Land capability study for horticulture in the Swan Valley

J M. Campbell-Clause

Geoff Allan Moore

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Land capability study for horticulture in the Swan Valley

By J. Campbell Clause and G. A. Moore

DEPARTMENT OF AGRICULTURE - WESTERN AUSTRALIA
Land capability study for

HORTICULTURE IN
THE SWAN VALLEY

By: J. Campbell Clause and G. A. Moore

Editors: L.J. Snell and D.A.W. Johnston
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The authors:
J. Campbell Clause, Research Officer, Viticulture Branch, Division of Horticulture; and G.A. Moore, Research Officer, Land Evaluation Group, Division of Resource Management, Department of Agriculture, Western Australia.

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The Swan Valley is an important agricultural, recreational, tourist and heritage area in which there are a number of competing land uses because of its location close to Perth. The traditional agricultural use, mainly centred around the viticulture industry, has to compete with tourist development, urban encroachment, hobby farms and clay extraction. The major objective of this report was to identify any areas of prime horticultural land which should be retained for that purpose.

A land capability study was done using the existing soil series map of the Swan Valley (Pym 1955), which covers most of the Swan Valley Policy Area. The map units were assessed for 11 land qualities (e.g. site drainage, rooting conditions) which were then related to the land use requirements to derive the land capability ratings. The ratings for six horticultural crops: table grapes, wine grapes, dried vine fruit, stone fruit, citrus and market gardening were determined. Map production was done by the Department of Agriculture’s Geographic Information System (digital data base) to enable interpretative analysis and reproduction of special purpose maps.

A corridor of prime horticultural land for table grape production has been identified adjacent to the Swan River and corresponds to the Swan, Belhus, Houghton, Pyrton, Herne and Cruse soil series. This corridor would be suitable for a special horticultural zone within the Swan Valley, with the boundaries corresponding to the existing Swan Valley Rural Zone. Tight control over alternative land uses would be needed to protect the prime agricultural land and ensure the long term prosperity of the table grape industry. The competing land uses include subdivision, tourism and clay extraction.

Included with the report are maps showing the soil types (1:25,000) (Pym 1955) and the land capability for table grapes (1:50,000). Land capability maps for the other land uses assessed are available from the Department of Agriculture on request.
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The Swan Valley is one of the most important agricultural, recreational and tourist assets close to Perth. The valley contains alluvial soils which are highly productive for horticulture. The climate and soils of the valley permit the production of premium quality table grapes and quality wines, particularly the fortified styles. The valley also contains reserves of plastic clay used for brick making. Large brick works and tile works are located at Middle Swan and Caversham. The valley's scenic and historic attractions, coupled with its proximity to Perth, make it a prominent tourist attraction with outstanding potential for further development. These same attractions are the reasons why the Swan Valley is under pressure from a number of conflicting land uses, including urban expansion, hobby farms and development.

The Swan Valley has been an important viticultural area with production peaking in the late 1940s when about 4000 ha were under vines. The main industry at that time was dried fruit with small but significant wine making and table grape industries. The area planted to vines has contracted to about 600 ha (1988), with large areas of Mongin series and marginal Herne series soils being taken out of production. The reason for this decline can be attributed to changing economic conditions, management technique problems, waterlogging and the move away from dried fruit production. Land use in 1953 is compared with land use in 1988 (Figure 1 and Figure 2 respectively). Table grape production is now the most important industry in the Swan Valley, supplying both the local and export markets. High returns per unit area are possible on suitable soils using sound management techniques. Also significant is the winemaking industry, with about 80% of the State's wine being made in the valley.

Horticulture in the Swan Valley is under pressure from a number of other land uses. Urban encroachment and subdivision for semirural living, with the subsequent increase in land values within the valley, probably pose the greatest threat, although clay excavation, tourism and other uses (e.g. schools) are also eroding the horticultural base. The valley starts only 15 km from the centre of Perth and is adjacent to the burgeoning urban sprawl of the greater Perth Metropolitan Area. Other factors which may increase demand for residential and hobby farming land in the valley include the significant price increase for residential land near Perth in the late 1980s and the development pressures created by the adjoining semi-rural subdivision at Brigadoon and the 'Vines Country Club' with accompanying residential development.
Figure 1. Existing land use map of the Swan Valley vineyard area (1953)
(From Pym 1955).
Figure 2. Land use map (March 1988).
(base map courtesy of Department of Planning and Urban Development)
Swan Valley Policy

The Government of Western Australia’s Swan Valley Policy (Anon. 1985) identifies a need to revitalize and conserve the Swan Valley. The Government makes a commitment in its policy to retaining the Swan Valley as an agricultural, recreational and tourist asset. The Swan Valley Policy ‘Specific Objective 9’, states that future planning for the valley’s natural and built environment should:

1. ensure that important resources such as horticultural soils are not jeopardized by incompatible development or subdivision;
2. minimize developments and activities which conflict with the quality of the valley as a horticultural, tourist and recreational area (Anon. 1985).

The Government’s primary objective for conservation and planning is to conserve and enhance the Swan Valley’s unique resources. As a means to achieving this, two zones have been identified and implemented by the Shire of Swan:

(a) the Swan Valley Rural Zone; and
(b) a rural living zone (to act as a buffer to the Rural Zone).

The objective of zoning is to ‘promote the area primarily as a horticultural, recreational, tourism and landscape resource, with areas containing high quality horticultural soils and scarce plastic clays receiving special protection’. (Shire of Swan Town Planning Scheme No. 9 Section 8.2.2).

The Shire of Swan’s existing Swan Valley Rural Zone (Figure 8) occupies the central, highly productive part of the Swan Valley Policy Area. It is supported by statements of planning policy such as ‘the Council shall not approve of any development which would jeopardize the high quality horticultural soils’. However, high quality horticultural soils and land considered suitable for horticulture are not defined nor described or located on a map. These planning policy statements are thus of limited value in providing the Council with adequate information with which to assess the impact of development proposals on the valley and to achieve the objective of the zoning.

The Swan Valley Policy lists specific objectives and indicates Government action, including the management of groundwater resources in the Swan Valley. This involved a review of the current policy of the Water Authority of Western Australia (in this publication referred to as the Water Authority) in relation to water supply. In, ‘Groundwater allocation policy and management study’, D.A. Hooper (1986, unpublished) recommended that the Department of Agriculture prepare a detailed land use map and land capability description for viticulture.

A report for the State Planning Commission by Nesic (1987), ‘Proposed Swan Valley land use and subdivision’, included a preliminary land capability assessment for viticulture. The fact that arbitrary planning decisions were included in the land capability assessment, and it lacked information on areas considered marginally suitable, or not suitable, are shortcomings. Our report aims to overcome these deficiencies.

Study Objectives

The objectives were:

- To provide a detailed land capability assessment for horticulture, in particular for viticulture, in the Swan Valley.
- To identify any prime horticultural land which should be retained for horticulture.
- To provide an updated land use map for the Swan Valley.

To fulfil the Swan Valley Policy objectives, it was necessary to make a clear delineation of the suitable horticultural soils in the Swan Valley. Even though there is extensive local knowledge on the performance of vines on various soil types in the Swan Valley, there was a need to formalize this knowledge. This report combines the available knowledge of the physical resources of the valley (climate, soils and groundwater) and assesses the horticultural capability.
The study area

The Swan Valley is a scenic, semi-rural area commencing 15 km from the Perth city centre. The study area discussed in this report includes two overlapping areas: the Swan Valley Policy Area and the Swan Groundwater Area (Figure 3).

The borders of the Swan Valley Policy Area are West Swan Road in the west and the foothills of the Darling Range in the east. To the north it extends to Ellen Brook and, in the south, to the Swan River, north-east of Guildford.

The Swan Valley is a licensed groundwater area under the control of the Water Authority. The Swan Groundwater Area includes most of the policy area, but is larger. It extends north from the Great Eastern Highway to Warbrook Road in Bullsbrook. In the east to the foothills of the Darling Scarp and, to the west, it extends through to the low sandhill country west of West Swan Road.

Figure 3. Location of the study area
This study involved the assessment of existing soil maps for a range of viticultural and other horticultural crops.

Soil maps used

Some six published and unpublished soil maps cover all or part of the study area. Two of these maps (Northcote et al. 1967, Churchward and McArthur 1980) were, at a broad scale, unsuitable for a detailed land capability assessment. The spatial distribution of the most detailed soil maps in the Swan Valley is shown in Figure 4. Most of the Swan Valley Policy Area is covered by a detailed soil series map (Pym 1955) which involved a survey on a 200 m grid together with aerial photographic interpretation. The main deficiency of the map for land capability assessment is the variable drainage status of the Herne and Cruse Soil Series as mapped. We did not have the resources to re-map these two units which cover a significant area.

The soil series map (Pym 1955) and the environmental geology maps were used for the land capability assessment. The land capability interpretive maps are only available for the area covered by the soil series map (Pym 1955). (See Appendix 5 for the list of maps available). In our work, map units which have similar values for the land qualities assessed, and essentially similar soil profiles, have been grouped together. For example, Lotons sand, Lotons gravelly sand and Lotons gravelly sandy loam have been grouped together under Lotons series.

The map units were evaluated for 11 land qualities (Table 2). The evaluation consisted of information from the relevant published reports, local experience and field investigations. The field investigations involved detailed soil profile descriptions using the 'Australian soil and land survey field handbook' (McDonald et al. 1984) at 50 representative sites (determined from the map unit description), together with the physical features of the landscape including the topography and rock outcrop. In addition, reference was made to site description sheets from the Darling Range rural land capability study (King and Wells 1990) and from the CSIRO archives.

An updated map of land use in the Swan Valley was prepared through the interpretation of aerial photographs taken in April 1987, together with field verification. The land use requirements and factor rating tables for the viticultural land uses were developed in consultation with I. Cameron (Department of Agriculture). The factor rating tables for citrus, stone fruit and market gardening were adapted from a study of the potential for horticulture on the Swan Coastal Plain (Moore 1990). For flood hazard assessment, see the Water Authority.

Land capability classification

Land capability is the ability of the land to sustain a specific use without undesirable on-site or off-site land degradation. The procedure used for deriving capability ratings for the six types of land use considered is described.

Capability classes

A five class system is used by the Department of Agriculture to describe land capability. Land capability classes indicate the degree of severity of physical limitations to a particular land use, together with levels of management needed to contain any subsequent land degradation (Table 1). It ranges from Class I, which signifies a very high capability with few limitations for the proposed land use, to Class V which is regarded as prohibitive for the specified use. The quality, or qualities which are the limiting factors for a land use are shown as letter notations (Table 2). No letter notation is shown for units rated as Class I, because there are no significant limiting factors.

Derivation of the classification:

The land capability methodology was broadly based upon the land evaluation guidelines developed by the Food and Agriculture Organization of the United Nations (FAO 1979, 1983). The procedure is outlined in Figure 5.
Figure 4. Soil maps available of the Swan Valley
Steps involved:

- Define the land use(s)
  A land capability classification inherently relies on specification of the land use type. For example, land may be too waterlogged for vines, although it is ideal for grazing. In this study, the land use types considered relevant to horticulture in the Swan Valley were: table grapes, wine grapes, dried vine fruit, stone fruit, citrus and market gardening.

- Select the relevant land qualities, considering the land use(s) to be assessed.
  Land qualities are those attributes of land which influence its capability for a specified use. The land qualities selected are listed in Table 2. Descriptions of each land quality, plus value descriptions, are in Appendix 3.

- Formulate the ‘land use requirements’ in terms of land quality values (i.e. factor rating tables).

Table 2. Land qualities assessed for each map unit

<table>
<thead>
<tr>
<th>Land quality</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site drainage</td>
<td>i</td>
</tr>
<tr>
<td>Moisture holding capacity</td>
<td>m</td>
</tr>
<tr>
<td>Nutrient retention</td>
<td>n</td>
</tr>
<tr>
<td>Rooting conditions</td>
<td>r</td>
</tr>
<tr>
<td>Salinity hazard</td>
<td>y</td>
</tr>
<tr>
<td>Flood hazard</td>
<td>f</td>
</tr>
<tr>
<td>Soil workability</td>
<td>k</td>
</tr>
<tr>
<td>Potential for mechanization</td>
<td>q</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>w</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>e</td>
</tr>
<tr>
<td>Soil structural decline hazard</td>
<td>s</td>
</tr>
</tbody>
</table>

The factor rating tables for each land use are in Appendix 4.

- Assess each map unit for each land quality.

See Appendix 2 for a summary of the assessed land quality values for each map unit.

- Matching of requirements using factor rating tables.

- Land capability classification as determined by the ‘most limiting factor’ method.

The capability ratings for each map unit are summarized in Appendix 1, with the limiting land qualities shown as letter notations. For example, an area designated as IIImn for citrus has only a fair capability for producing citrus fruit, because of the moisture holding capacity and nutrient availability of the soils.

Figure 5. Flow diagram showing land capability assessment procedure
The Swan Valley (Latitude 31° 53'S Longitude 116°00') has an average altitude of 10-15 m. The climate is typically Mediterranean with a hot dry summer and a mild, wet winter.

Olmo (1956) believed that the climate of the Swan Valley was especially well suited to the production of currants, table grapes and sweet dessert wines. It is also well suited to other horticultural crops with a low chilling requirement.

The Swan Valley is a warm viticultural area, with a total of 2388°C day degrees between October and April. High growing season temperatures characteristic of the Swan Valley are important in the production of dessert wines, sweet table grapes and for drying. They are important for two reasons; to produce adequate foliage to ripen the crop and to achieve a high sugar content in the berries.

Temperature data for the Upper Swan Research Station, which is slightly north of the main grape growing area, is shown in Table 3. Mean daily maximum temperatures vary from 18.2°C for July to 33.6°C for January and February. The highest temperature recorded in summer was 46.2°C in January 1980. Heat wave conditions when temperatures are high for several days, can cause sunburn to vine, melon, vegetable and fruit crops.

Mean daily minimum temperatures vary between 6.7°C for August to 16.2°C for February with the lowest recorded, -0.9°C in June 1968. Most deciduous plants have some requirements for exposure to low temperatures during the dormant phase (chilling hours). The lack of chilling hours restricts the potential for deciduous plants that have a moderate to high chilling requirement.

There are about six days per year when the temperature falls below 2.2°C. On average, there are no days where the temperature drops below 0°C. However, frosts do occasionally occur in June, July, August and September. Spring frosts can be particularly damaging to vines.

Mean daily terrestrial temperature varies between 4.3 and 13.9°C, the lowest recorded was -4.3°C in July, 1969. On average, there are three days per year when terrestrial temperature falls below -0.9°C.

The annual average rainfall is about 736 mm, mostly falling during winter (Table 3). Rain from April to September is important for replenishing subsoil moisture storage. On average, there are 133 mm of rain in spring (September-November) and only 31 mm through the ripening period (December-February). This pattern is advantageous as frequent falls of rain during the ripening period, accompanied by high humidity, can result in fungal diseases and splitting of the grape berries.

Hail is not frequent, however, it has occurred in March, June, July, August, September, October and November. Hail can damage foliage and fruit if it comes at a critical stage in the growth or ripening phase.

Evaporation in the Swan Valley is greater than the average annual rainfall. Evaporation over the growing season (October-March) is 1460 mm. For summer growing crops, such as vines, this moisture deficit must be made up from soil moisture reserves or irrigation.
Table 3. Climatic data for the Upper Swan Research Station

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean daily maximum (°C)</td>
<td>33.6</td>
<td>33.6</td>
<td>31.1</td>
<td>26.4</td>
<td>22.2</td>
<td>18.9</td>
<td>18.2</td>
<td>18.7</td>
<td>20.3</td>
<td>23.7</td>
<td>27.1</td>
<td>31.2</td>
</tr>
<tr>
<td>Mean daily minimum (°C)</td>
<td>15.2</td>
<td>16.2</td>
<td>14.5</td>
<td>11.5</td>
<td>9.4</td>
<td>8.5</td>
<td>7.7</td>
<td>6.7</td>
<td>7.8</td>
<td>8.7</td>
<td>10.9</td>
<td>13.7</td>
</tr>
<tr>
<td>Days 2.2° or lower</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Days 0° or lower</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mean daily terrestrial (°C)</td>
<td>12.6</td>
<td>13.9</td>
<td>11.9</td>
<td>9.6</td>
<td>6.8</td>
<td>5.8</td>
<td>5.1</td>
<td>4.3</td>
<td>5.0</td>
<td>6.3</td>
<td>8.3</td>
<td>11.7</td>
</tr>
<tr>
<td>Rainfall mm (31 years)</td>
<td>8</td>
<td>12</td>
<td>14</td>
<td>39</td>
<td>99</td>
<td>154</td>
<td>160</td>
<td>106</td>
<td>68</td>
<td>42</td>
<td>23</td>
<td>11</td>
</tr>
<tr>
<td>Relative humidity %</td>
<td>48</td>
<td>49</td>
<td>52</td>
<td>65</td>
<td>72</td>
<td>79</td>
<td>80</td>
<td>77</td>
<td>71</td>
<td>59</td>
<td>55</td>
<td>47</td>
</tr>
<tr>
<td>Evaporation (mm)</td>
<td>213.7</td>
<td>196.4</td>
<td>176.8</td>
<td>110.6</td>
<td>75.9</td>
<td>68.8</td>
<td>45.9</td>
<td>53.0</td>
<td>78.5</td>
<td>120.7</td>
<td>181.8</td>
<td>253.9</td>
</tr>
</tbody>
</table>

The Swan Valley is renowned for its windiness. In spring, the strongest winds are generally from the west and south-west and can damage vine and fruit tree shoots, resulting in a loss of production. Storm winds in spring can cause extensive shoot damage to vines, especially to susceptible varieties in exposed situations. In summer, the prevailing winds are predominantly from the east during the night and morning and from the south-west in the afternoon (Figure 6). Strong, hot easterlies can damage fruit, foliage and lower yield. The sea breeze is generally beneficial through the lowering of temperatures, although, when strong, can damage crops. The areas most susceptible to the winds from the east are the localities east of the Swan River i.e. (Middle Swan, Herne Hill, Millendon and Upper Swan). Caversham and the area south of Henley Brook appear to be more favourably situated to withstand winds from the east to south-east.

Figure 6. Wind roses for the Upper Swan Research Station
Groundwater resources

The Rights in Water and Irrigation Act of 1914 provides for areas to be proclaimed and within these areas construction of wells and use of groundwater must be licensed. The Swan Groundwater Area was proclaimed in September 1975, following concern over the use of water from the Leederville aquifer in areas where the aquifer is non-artesian and not subject to controls. During 1981, it became apparent that demand needed to be controlled. The abstraction from the upper Leederville aquifer (private 3.5 x 10^6 m^3/a, public requirements 1.3 x 10^6 m^3/a; total 4.8 x 10^6 m^3/a) approaches the flow rate which is believed to be 5 x 10^6 m^3/a. Thus the groundwater is fully committed to existing users (R.E. Banyard 1985, unpublished). This led to the formation of the ‘Swan Groundwater Advisory Committee’ to manage the groundwater resources of the Swan Valley. Figure 7 shows the boundary of the Swan Groundwater Area and the ten sub-areas. The sub-areas include, from north to south; North, Upper Swan, Belhus, Millendon, Henley Brook, Herne Hill, West Swan, Middle Swan, Caversham and South. The fresh groundwater resources of the Swan Valley are within three main aquifer systems, the unconfined superficial formations and the confined Osborne and Leederville formations. The aquifers are described in Appendix 6.

Groundwater availability

The estimated availability and license allocations within each sub-area are summarized in Table 4. This is an updated version of Table 1 derived from D.A. Hooper (1986, unpublished) and it takes into account the results of the pasture survey (Anon 1986), plus subsequent licenses which have been issued. The availability figures as given by D.A. Hooper (1986, unpublished) originate in the reports by Allen (1980) and Steen (1984) and are equivalent to 100% throughflow.

The superficial formations can be considered as the eastern and western superficial depending upon where they are in relation to the Swan River. There is considerable water available in the western superficial formation in the North, Belhus and Henley Brook sub-areas. This water is mainly in areas of deep sandy soils on the western side of the sub-area. There are more limited supplies unallocated in Caversham, South and West Swan. It appears as if the groundwater in the eastern superficial is fully committed (see Table 4). The Water Authority has reservations about the validity of the water availability data for this area as given by D.A. Hooper (1986, unpublished). It is difficult to reliably determine the available water resources of the eastern superficial, because two adjacent bores (within 150 m) can have substantially different abstraction rates (J. Seymour, personal communication). The allocation to availability percentage from the superficial formation for the Millendon, Herne Hill and Middle Swan sub-areas are probably misleading. In the future, there could be a change in policy for water allocations from the eastern superficial adjacent to the Swan River. If water is available then users may be able to extract it (R.E. Banyard, personal communication).

The Leederville formation is the main aquifer used for irrigating horticultural crops in the Swan Valley. In all the sub-areas, apart from Herne Hill, Millendon and South there are limited quantities presently unallocated. The Osborne formation has a fairly low overall allocation to availability ratio. Most of the unallocated
Figure 7. The Swan Groundwater Area and the ten sub-areas
groundwater is in the North, Belhus and Henley Brook sub-areas underly ing sandy soils.

The available data show there is no unallocated water in any of the aquifers for Herne Hill and Millendon (Table 4). D.A. Hooper (1986, unpublished) states that 58% and 48% of the total allocation is for horticulture (viticulture and market gardening) in Herne Hill and Millendon respectively. In these two sub-areas, where availability is critical, then allocation for pasture and fodder could be reduced. Substantial savings in water efficiency could also be achieved by using low volume irrigation systems scheduled efficiently.

Allocation

The Water Authority’s current allocation policy for the Swan Groundwater Area is as described by Banyard (1985, unpublished). The groundwater management objectives are:

- The water resource must not be significantly and permanently damaged from over use or pollution.
- The present users should be protected wherever reasonable.
- The groundwater flow systems must be measured and monitored.
- Water use must be monitored.
- The user of most benefit to the community should be given highest priority.
- Water must be used efficiently.

To ensure the equitable distribution of groundwater, the Swan Groundwater Advisory Committee (with representatives from the Water Authority, Grape Growers Association, Swan Valley and Regional Winemakers Association, Shire of Swan and the Department of Agriculture) advises the Water Authority on groundwater matters and license applications. The primary objective of the committee is to harvest water at a sustainable level to conserve and protect the long term security of the groundwater resources of the region and ensure that the use of the resource benefits as many people as possible.

The Swan Groundwater Advisory Committee adopted the following detailed objectives to complement this primary objective.

- To ensure that, where possible, a reasonable quantity of water is available to existing enterprises dependent upon a continued supply of good quality groundwater.
- To promote the allocation of the available groundwater resource on a basis which provides the most beneficial use to the community.
- To encourage efficiency in water use through improvements to methods of agriculture and irrigation and encourage the development of low water use crops, such as vines, consistent with the regional planning and land use objectives for the area.

Relevant strategies have been implemented to meet these objectives. In the future the demand for the limited water supplies will be greater. R.E. Banyard (1985, unpublished) states:

‘As development occurs the conditions and restrictions on water use will become more stringent and users will be required to be more efficient in water use. Re-allocation of existing use to more beneficial users must be considered.’

As a result of the study by D.A. Hooper (1986, unpublished), the introduction of an Allocation Priority System was recommended.

This should be based on the following criteria:

(a) Priority areas.
(b) Priority in efficient use.
(c) Priority uses.
(d) Priority for quality requirements.
(e) Priority for low volume irrigation.
(f) Priority of allocation for specific uses.

The system being used in the Swan Groundwater Area follows these criteria. In the different sub-areas availability and allocation is determined for each aquifer. Licences are granted specifying the amount of water that can be used and the depth from which water can be drawn. Priority is given to horticulture and more specifically to viticulture, with up to 5000 KL/ha being allocated for table grapes and 3000 KL/ha for wine grapes per year. Where water is scarce, the system works on a first in first served basis.

Table 4. Groundwater availability and licensed allocations for the Swan Groundwater Area

<table>
<thead>
<tr>
<th>Sub-area</th>
<th>Superficial</th>
<th>Leederville</th>
<th>Osborne</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avail.</td>
<td>Alloc.</td>
<td>% (1)</td>
</tr>
<tr>
<td></td>
<td>1000’s cubic metres per year</td>
<td>1000’s cubic metres per year</td>
<td></td>
</tr>
<tr>
<td>Belhus</td>
<td>6,000</td>
<td>884</td>
<td>15</td>
</tr>
<tr>
<td>Caversham</td>
<td>800</td>
<td>192</td>
<td>24</td>
</tr>
<tr>
<td>Henley Brook</td>
<td>1750</td>
<td>338</td>
<td>19</td>
</tr>
<tr>
<td>Herne Hill</td>
<td>200</td>
<td>379</td>
<td>190</td>
</tr>
<tr>
<td>Millendon</td>
<td>250</td>
<td>460</td>
<td>184</td>
</tr>
<tr>
<td>Middle Swan</td>
<td>75</td>
<td>503</td>
<td>670</td>
</tr>
<tr>
<td>North</td>
<td>7,000</td>
<td>226</td>
<td>3</td>
</tr>
<tr>
<td>South</td>
<td>270</td>
<td>60</td>
<td>22</td>
</tr>
<tr>
<td>Upper Swan</td>
<td>223</td>
<td>488</td>
<td>73</td>
</tr>
<tr>
<td>West Swan</td>
<td>600</td>
<td>122</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>16,945</td>
<td>3,703</td>
<td>5,500</td>
</tr>
</tbody>
</table>

(1) Percentage of available groundwater allocated as at March 24, 1988.
Viticulture

The general requirements for vines are described, followed by the specific requirements for table grapes, wine grapes and dried vine fruit.

Climate

Grapevines will grow under a range of climatic conditions, although they prefer a long, warm dry spell as they mature. Low temperatures have a minimal effect other than to slow growth. Grapevines are frost tolerant during the dormant phase, although highly susceptible to spring frosts. High temperatures (> 35°C) can cause sunburn of the fruit if the crop has not been previously conditioned by warm weather. Very hot conditions (> 40°C) can cause severe sunburn, although damage can be controlled with management techniques (i.e. adequate foliage, proper trellising, irrigation management). Rain at harvest can cause severe fruit damage, while a low relative humidity reduces the incidence of fungal diseases. Light winds can be beneficial during summer by reducing the extremes of temperature and humidity. Moderate and strong winds can have detrimental effects through:

- Damage to young vines; strong winds can physically damage young vines in their first and second seasons and make training of the vine difficult. It can also cause losses and damage through sand blasting, desiccation, shoot rubbing and breakages.
- Lodging of foliage exposing fruit and/or crowding of foliage, reducing light penetration.
- Increasing the water loss from the root zone, through evaporation.
- Persistent strong winds can damage foliage, reducing the effective leaf area for photosynthesis.
- Both young vines and older vines make better growth if protected from strong winds, because at low wind speeds stomatal conductance is higher.

Soil requirements

Grapevines are adapted to a wide range of soil types ranging from coarse gravelly sands to clays, although they will perform better on certain soils. Soils with a loam to fine sandy loam texture are considered ideal because of their drainage, water-holding capacity, nutrient retention and rooting conditions. Preference for loams over fine sands diminishes as soil depth increases. Deep loams may stimulate excessive vine growth at the expense of yield and quality. Grapevines are tolerant of water-logging during the dormant phase, although not during the growing period. If grown in soils with no impeding layers they will develop a deep (> 3 m), extensive root system.

The depth of surface soil is important, as it is the most fertile part of the soil profile. As the bulk of the vine’s feeding roots are found in the top 15-60 cm, the surface soil should be 30-45 cm deep or preferably 45-60 cm deep (Webber 1976a). To maximize the depth of usable surface soil, a minimum tillage system is preferred. The available soil volume is maximized, the structure is maintained or improved and compaction is reduced.
Hardpans induced by excessive traffic and shallow cultivation are a common problem in vineyards in the Swan Valley, resulting in root and water penetration problems. Where they are relatively close to the surface they can be successfully ripped (Smith et al. 1969). The presence of an impeding layer restricts root penetration, affecting the volume of soil the roots can explore. It can also result in drainage problems and the development of temporary perched water tables. Herne and Cruse soils have almost impermeable clay subsoils in some low flat areas, resulting in poor internal and external drainage. Under rainfall, impeding layers at a depth of < 1 m may cause problems unless the land is gently sloping and has good downslope drainage. Under irrigation, impeding layers in the top 1-2 m often result in perched water tables and the need to install drains.

The nutrient requirements of grapevines are small compared with those of more intensive horticultural crops, partly because the pruning and leaves are returned to the soil. Each tonne of fresh grapes removes 0.6 kg N, 0.17 kg P and 2.1 kg K (Webber 1976b). Also, vine root systems are wide ranging in their search for nutrients and water. The extent to which annual fertilizer applications will be required depends on the inherent fertility of the soil, vine vigour, yield and any leaching losses. The alluvial soils in the Swan Valley are comparatively fertile and only light annual applications of macro-nutrients are recommended. On the sandy and gravelly soils there should be annual applications of fertilizer based on leaf analysis.

Irrigation

Irrigation requirements vary depending on the type of viticulture. Table grapes normally require irrigation over the growing season, while wine grapes and dried fruit can be grown with supplementary irrigation or on soil moisture reserves. The crop demand for water changes over the growing season. Evapotranspiration is low at the start of the season, but increases as vine foliage develops and days become longer and warmer, reaching a peak when the fruit is rapidly sizing, then declining after harvest. Sensitivity to moisture stress depends on the growth stage. The most critical growth stages are flowering, fruit set, lag phase and verasion.

Three main types of irrigation systems are used in the Swan Valley: furrow, sprinkler and micro-irrigation. To improve water use efficiency, the Department of Agriculture encourages the adoption of micro-irrigation. The water quality should preferably have a salinity level < 280 mS/m. Irrigation water with an electrical conductivity > 280 mS/m may cause problems with associated excessive salts and toxic levels of chloride or sodium. When irrigating with water of marginal quality, sprinkler irrigation should be avoided or only night watering practiced. With high salinity water only use micro-irrigation. A leaching component should be applied to avoid a build-up of salts in the root zone.

Management

The management requirements specific to the type of viticulture are:

Table grapes

This land use type refers to the commercial production of irrigated table grapes. Traditionally, the Swan Valley has been a table grape growing area, because of the soil types, climate and proximity to both the local market and facilities for the export trade.

The soil requirements for table grape production are more stringent than for wine grape or dried vine fruit production. They require deep (> 75 cm), well drained soil, preferably with a sandy loam to loam texture. Naturally fertile soils are an advantage and do not result in a loss of quality as with dried vine fruit.

The irrigation requirement for table grapes varies over the growing season. The peak crop factors* are 0.45 on medium to heavy textured soil and 0.55 on sandy soils.

* Crop factor = a percentage of Class A pan evaporation.

This equates over the growing season to a water requirement of about 5000 m³/ha. Low volume micro-sprinkler or trickle systems are the preferred irrigation method. Vine rows should be planted to offer the least resistance to the prevailing wind. Wind-breaks should be used in exposed sites. On fertile soils, which result in vigorous vine growth, a double spacing link trellis should be used, while, with less vigorous vines, the trellising should be adequate.

A number of varieties are recommended for the Swan Valley including Flame Seedless, Emporer (clone 3A 2295), Sultana (clone MS), Queen, Italia, Perlette, Cardinal (clone 2290) and Ribier (I. Cameron, personal communication). The recommended rootstocks selected to overcome nematodes and drought are Schwarzmans, 34EM, Ramsey 1613 and Dogridge.

On suitable soils (Class I, II, III) it is possible to achieve average yields of 25-30 kg of marketable fruit per vine, or 30 t/ha assuming a planting density of 1190 vines per ha. The minimum viable area required at these marketable yields is 4.5-5.5 ha, providing fruit for marketing on both the local and export markets. Quality is at least as important as quantity for table grape production. The most successful way of achieving premium quality table grapes is through adopting the latest management techniques. These include using rootstocks in combination with the new improved varieties, micro-irrigation, wind-breaks and adequate disease and pest control.

Wine grapes

This land use refers to the commercial production of grapes for wine making with supplementary irrigation. In the Swan Valley, the principle wine producing vineyards are located on the Belhus, Houghton and Swan series of the alluvial soils, on the Cruse and Herne series of the plain and on the Lotons series of the foothills. The wine varieties Chenin Blanc, Verdelho, Serrillon, Chardonnay, Shiraz, Cabernet Sauvignon, Pedro and Tokay are widely grown and suited to the area.
Wine grapes can be grown on a range of soil types, although they should preferably be moderately to well drained. High soil fertility may adversely affect wine quality. The fruit tends to be of a coarse texture with a poorly balanced composition. A variety of soil types are desirable if a winery is to make a number of different wines.

Irrigated vines will establish more quickly than non-irrigated vines, resulting in larger crops during the early seasons and a more uniform vineyard. On suitable soils in the Swan Valley, yields up to 10 t/ha for non-irrigated vineyards can be obtained, although at this level of production wine quality is affected. Supplementary irrigation during the early to mid-season period is beneficial. There is growing support for the view that irrigation up to veraison has no deleterious effect on wine quality and results in significantly higher yields (Jamieson 1976). A level of 15 t/ha on suitable soils with proper irrigation management would give maximum results from the interaction of yield and wine quality. A minimum area of 12-14 ha is required to remain viable (O. Cameron, personal communications).

Nematode resistant rootstock is required for wine grape production and Schwarzmman, 34EM and Ramsey have been successfully used. Wine grapes are generally planted closer than table grapes and should be trellised according to vine vigour.

Dried vine fruit

This land use refers to the commercial production of dried vine fruit with supplementary irrigation during the summer. In Western Australia, the main areas of dried fruit production are the Swan Valley, Chittering Valley, Muchea and Bindoon. No vigneron is wholly dependent on dried fruit production for his/her income. The dried fruit industry is based on the production of sultanas, raisins and currants from Zante Currant.

Currant vines will grow on a wide range of soil types, but prefer well drained soils with a friable clay subsoil 30-75 cm below ground level. Deep, fertile loams tend to produce high yields of poorly coloured watery fruit.

Vines for dried fruit production can be grown without irrigation, although significant yield benefits can be achieved with supplementary or regular irrigation. A single irrigation of 75 mm applied in December increases yield by about
Citrus were once the second most adverse effects of wind, more prof-
atively used, although it has a major fault in that the berries are
and trellis design depend on vine
Rainfall is important horticultural crop after
resulted in only a remnant citrus
Nematode resistant root stock is
required and Ramsey has proved
to be the best. Planting densities
and trellis design depend on vine
vigour and irrigation.

On well drained soils with sup-
plementary irrigation, yields
should be between 3-6 t/ha, or up
to 7 t/ha with regular irrigation.
The minimum viable area required
is 12-15 ha assuming yields > 2
In the Swan Valley, mainly 'old' low-chill
peach varieties, which have been
superseded by new improved,
early maturing varieties. Small
plantings of the new varieties have
proved successful.

Climate

Citrus are a warm temperature,
Mediterranean crop. They are sen-
titive to low humidity levels and
the optimum temperature (mean
daily) for growth is 23-30°C, al-
though they will still grow if the
temperature is in the range 13-
35°C. Citrus are reasonably resis-
tant to frosts, except in late spring.
They have no chilling require-
ments, although they do require a
period of cool weather for proper
colour development of the fruit.

Strong winds can be very damag-
ing to the quality of the fruit.

Soil requirements
Citrus roots have a high oxygen
requirement, so a well drained site
is essential. Deep, light to medium
textured soils are preferred and the
water table should not come within
1-3 m of the surface. A well aerated
site also lessens the problems with
Phytophthora citrophthora, a major
root pathogen of citrus. In a soil
free of imped ing layers citrus will
send down a tap-root (> 2 m). The
majority of the horizontal lateral
roots are in the top 50 cm and 90%
occur in the top metre (Landon
1984). Citrus can tolerate soil pH's
from 5-8. They will grow well on
deep, fertile sandy soils, although
production on the highly bleached
coarse sands is marginal. With their
lower moisture holding capacity,
sandy soils have the advantage of
warming up earlier in spring.

Irrigation
Citrus have a lower irrigation
requirement than most horticultu-
ral crops and are well adapted to
controlling transpiration losses,
even under windy conditions. A
crop factor of 0.6 on medium to
heavy textured soils and 0.8 on
sandy soils will suffice. Citrus are
sensitive to saline irrigation water
and the irrigation water salinity
level should be < 150 mS/m. Care
must be taken if the irrigation
water is of marginal salinity status,
avoiding leaf contact and applying
a leaching factor. Low level spri-
klers or micro-sprinklers are the
preferred irrigation system.

Management

The main cultivars currently
(1990) grown in the Swan Valley
include Valencia and Navel or-
anges and the early season man-
darines, Early Imperial and Em-
peror. Citronelle is the major root
stock used, although it is suscepti-
ble to the root pathogens citrus
nematode, Tylenchulus semipne-
trans and Phytophthora citrophthora.
Resistant rootstocks such as Pon-
cius trifoliat a and Trager citrange
should be used when replanting an
area. Fertilizer requirements vary
depending on the soil type, tree age
and previous fertilizer history. The
normal planting densities used to be
7 m x 7 m (166 trees/ha), now
closer plantings of 5.1 x 5.1 m
(227 trees/ha) are favoured be-
cause of the earlier returns ob-
tained.

Stone fruit

This land use refers to the com-
mercial production of irrigated
stone fruit, including peaches, ne-
tarines, plums and apricots. The
Swan Valley is only suitable for the
production of 'low-chill' varieties.
There are some stone fruit in the
Swan Valley, mainly 'old' low-chill
peach varieties, which have been
superseded by new improved,
early maturing varieties. Small
plantings of the new varieties have
proved successful.

Climate

Stone fruit are cool to warm-
season crops. All stone fruit have a
chilling requirement (i.e. a period
with an air temperature of < 7°C)
for flower initiation, although the
actual requirement varies consider-
ably. The Swan Valley has a rela-
tively low number of chilling
hours, and it is only suitable for the
production of 'low-chill' varieties
of stone fruit. Peaches and nectar-
ines are susceptible to frosts and
the fruit is easily damaged by hail.

Soil requirements
Stone fruit can tolerate some
waterlogging during the dormant
phase, although they are highly
sensitive to waterlogging over the
growing season. Under anaerobic
conditions, hydrocyanic acid is
formed in the plant from the hy-
drolytic breakdown of a glycoside.
Stone fruit can be grown on a wide
range of soils as long as they are
well drained. Plums and apricots
can be grown successfully on rela-
tively shallow soils if Marianna
plum rootstock is used. For other
stone fruit and rootstocks, deep
soils (> 1 m) are required. Stone
fruit can be successfully grown on
the highly leached coarse sands
with careful management. They are
responsive to plant nutrients, and
regular applications of fertilizer (N,
P, K, Mg, Cu, Zn, Mn) are recom-
ended.
soil type, cultivation practice and
stone fruit are salt sensitive and
fruit vary depending on the
crop type and earliness or
October

Table 5. Crop factors for various stone fruit over the growing season
Paulin (1984)

<table>
<thead>
<tr>
<th>Crop</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peach-early</td>
<td>0.4</td>
<td>0.9</td>
<td>1.2</td>
<td>1.2/0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>-Mid</td>
<td>0.4</td>
<td>0.7</td>
<td>0.7/12</td>
<td>1.2</td>
<td>1.2/0.6</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>-Late</td>
<td>0.4</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7/1.2</td>
<td>1.2</td>
<td>1.2/0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Plum</td>
<td>0.4</td>
<td>0.8</td>
<td>0.9</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0/0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Apricot</td>
<td>0.4</td>
<td>0.8</td>
<td>0.9</td>
<td>1.0/0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.5</td>
</tr>
</tbody>
</table>

*Crop factor = a percentage of Class A pan evaporation.

Irrigation

The irrigation requirements for
stone fruit vary depending on the
planting density, tree spacing, age,
soil type, cultivation practice and
variety. The crop factors for stone
fruit vary from 0.4-1.20 depending
on the crop type and earliness or
lateness of the variety (Table 5). Stoney fruit are salt sensitive and
irrigation water of < 80 mS/m
should be used. Sprinkler, trickle
and micro-sprinkler irrigation can
all be used, although the latter is
the most satisfactory on sandy soils
under conditions of high evaporative
demand.

Management

Peaches and nectarines are suscep-
tible to nematode infestation
(root-knot nematode, Meloidogyne
spp. and root lesion nematode,
Pratylenchus spp.), and they should
be planted on resistant root stock.
Soil and root treatment is necessary
for diseases such as armillaria and
crown gall which cannot be con-
trolled by root stocks. High density
planting systems, with or without
trellis, are favoured for stone fruit.
These systems result in higher
yields per unit area than traditional
planting systems and the crop ma-
tures earlier, giving a significant
commercial advantage.

Market gardening

This land use refers to the year
round, commercial production of
vegetable crops and includes a
large number of plant species with
a range of requirements. Many
vegetable crops can be grouped
together; cole or brassica crops
(cauliflower, cabbages, Brussels
sprouts and broccoli), cucurbit
crops (cucumbers, rockmelons,
water-melons, pumpkins and
squash) and the root crops (pota-
toes, carrots, parsnips and turnips).
Market gardening has taken a sup-
plementary role to grape growing
in the Swan Valley with many
vignerons supplementing their in-
come from grapes with small mar-
tet gardens. The most common
crops grown are water-melons and
rockmelons, with about 50 ha cul-
tivated annually. Other crops in-
cluding pumpkins, cauliflowers, toma-
toes and cucumbers are grown on a
small scale (< 3 ha).

Climate

There is a whole range of vegeta-
table crops which vary from cool to
warm season. Most crops could be
grown in the Swan Valley for at
least part of the year (Moore 1990). The
cole crops are cool climate
crops and can withstand sub-zero
temperatures. The cucurbits are
warm season crops and prefer
mean temperatures in the range
from 18-30°C. The seed does not
germinate below about 15°C and the
plants are susceptible to frosts
and cold winds. The climatic re-
quirements for root crops vary
considerably, although most prefer
cool to temperate conditions.

Soil requirements

A well drained site is a require-
ment for most vegetable crops.
Root crops also require a loose, or
friable topsoil and a moderately
deep to deep soil. The high levels of
nutrients applied as organic ma-
nures and inorganic fertilizers re-
duce the advantages of using natu-
rally fertile soils. Vegetable crops
tend to be relatively shallow rooted
compared with other horticultural
crops, although rooting depths
vary considerably between species.
Vegetables such as cabbages,
beans, onions and lettuce tend to
have shallow rooting patterns with
most roots concentrated in the top
30-50 cm. Cucumbers, peppers,
peas (tap-root), water-melons and
tomatoes have root systems which
develop to a depth of 1-2 m, with
the main nutrient and water uptake
roots reaching a depth of about
70-120 cm (Landon 1984).

Irrigation

The irrigation requirements for
vegetable crops are generally
higher than for other horticultural
crops. The crop factor for mature
crops grown on sandy soils varies
from 1.2-1.5 evaporation reple-
ment. Vegetable crops are often
grown on sandy soils with low
water-holding capacity and, under
conditions of high evaporative
demand, some two to three waterings
day may be required. Vegetable
crops have a wide range of toler-
ance to irrigation water salinity
levels. Parsnips, green beans, celery
and cucumber are salt sensitive and
require water of < 80 mS/m, while
broccoli, tomatoes and artichokes
can tolerate up to 230 mS/m. Over-
head sprinklers are used to irrigate
vegetable crops, while the fruit
crops (tomatoes, water-melons,
rockmelons, cucumber) can be irri-
gated with low volume trickle sys-
tems, resulting in substantial water
savings (10-25%).

Management

Management varies depending
on the crop.
**Soils and land use limitations**

**Lotons series**

**Description:** Well drained lateritic, duplex soils with light textured A horizons (medium to coarse sand to sandy loam) containing large amounts of loose, ferruginous gravel overlying a yellow mottled sandy clay. The gravel layer may be quite thick (>1 m) and may be overlaid by a gravel-free layer of sand with organic matter. There are a number of different soil types and phases in the Lotons series; these soils are similar for horticulture and have been grouped for the land capability assessment.

**Limitations:** Generally few significant limitations, although the sandy A horizon has a low moisture holding capacity, and the high gravel content means applied phosphorus is readily fixed. The high gravel content also reduces the soil volume. The surface soil is quite wind erodible, particularly Lotons sand. The main limitation in the foothills area where this soil series is found is the general shortage of groundwater.

**Recommendations:** The Lotons soils with characteristics of good drainage and physical conditions are suitable for wine grape production. Distinctive quality wine can be produced, but only low yields are achieved. These soils are marginally suitable for table grapes and dried vine fruit because of their limited water-holding capacity, shortage of groundwater and wind exposure. The soils are suitable for other types of horticulture, although the potential is severely reduced by the limited groundwater.

**Range series**

**Description:**

Duplex soils with grey, coarse sand over a yellow, mottled, coarse, sandy clay at about 20-40 cm. The A horizon may contain ferruginous gravel and quartz fragments.

**Phases:** Range sand (shallow phase); subsoil encountered at a depth of 5 cm. Drainage and root- ing conditions result in this soil type being unsuitable for horticulture.

**Limitations:**

The internal drainage of Range sand and gravelly sand is restricted because of the shallow clay subsoil and its low permeability. Site drainage depends on the slope, with lateral movement on sloping sites. Soil depth limits production on these soils except for the deep phase.

**Recommendations:**

The Range series has low suitability for horticulture because of the restricted rooting conditions. Range sand (deep phase) has a greater rooting depth, although production is limited by the low water-holding capacity and shortage of groundwater for irrigation as this soil series is found in the foothills.

**Oakover series**

**Description:**

Red-brown, moderately well drained duplex soils. A typical profile has a brown, coarse loamy sand to coarse sandy loam surface texture over a brown, yellow-brown to red, mottled sandy clay subsoil at 30-60 cm. The A horizon frequently contains substantial amounts of loose, ferruginous gravel and or quartz fragments. The subsoil does not impede root growth and these soils are the most fertile of the foothill soils. There are a number of soil types and phases in this series, although they generally have similar characteristics for horticultural production.

**Limitations:**

Few limitations with this series, although some areas may be waterlogged for short periods during the winter. On sloping sites, drainage is improved through lateral movement.

LAND RESOURCES SERIES No. 6
Recommendations:
Soils of this series are moderately well drained, reasonably fertile and have good physical characteristics and are suitable for wine grape production. Distinctive high quality wine can be produced, however, yields are lower than on the alluvial soils. Table grape production is only marginal because of the strong winds encountered in the foothills area and the shortage of groundwater for irrigation. The exposed situation and limited groundwater resources severely limit the potential for other forms of horticulture.

**Mongin series**

Description:

Duplex soils with a light textured A horizon (coarse sand to coarse sandy loam) overlying a massive, cemented, grey or yellow, mottled sandy clay. Ferruginous gravel may be present in both the A and B horizons. The cemented subsoil impedes root development and results in a perched water table.

Phases: Mongin sand (swampy phase); The poorly drained areas of the Mongin series. Unsuitable for all forms of horticulture.

Mongin sand (deep phase); A transitional soil type between the normal Mongin series and the aeolian series (Pym 1955). A typical profile has 0.6-1.0 m of coarse light grey sand over a massive, mottled, sandy clay subsoil.

Limitations:

Site drainage is the overriding influence on vine performance and horticulture on these soils. The cemented nature of the subsoil results in a shallow effective soil depth. These soils have a low nutrient status and can be subject to salinization.

Recommendations:

Waterlogging during winter and spring severely restricts horticultural production on the Mongin series, apart from Mongin sand (deep phase). These soils were once used extensively for currant and wine grape production, although declining yields have seen most of the land revert to pasture. Production can be improved on marginal land by mounding the topsoil and installing a drainage system (i.e. spoon drains). Mongin sand (deep phase) is marginally suitable for market gardening, citrus and stone fruit production provided an adequate water supply is available.

**Herne series**

Description:

The Herne series consists of yellow duplex soils which may tend towards a gradational profile. There is a light textured A horizon (sand to sandy loam) of variable depth overlying a yellow, mottled medium clay subsoil. This series is characterized by a fine clay layer in the subsoil at varying depths from 70-170 cm (Pym 1955). Drainage is impeded by this layer resulting in a perched water table during the winter (C.V. Malcolm, unpublished data). External drainage of the Herne soils is generally limited, although dissection in some areas (mainly those nearest the Swan River and other streams) does allow some movement in this manner. The likelihood of waterlogging depends on the depth of the A horizon, the depth to the fine clay layer and the structure of the upper B horizon.

Phases: Herne sand (deep phase); A transitional soil between the duplex plain soils and the aeolian soils (Pym 1955). The typical profile consists of a light grey sandy A1 horizon stained with organic matter, followed by a conspicuously bleached A2 horizon overlying a clay subsoil at a depth of one metre.

Herne sand (brown phase); Herne soils with a brown coloured topsoil and often containing a significantly higher clay content. Vine performance on these soils is slightly superior to that on other Herne sands (Pym 1955).

Limitations:

Site drainage would be the major limitation for viticulture on most of the Herne series, although it does vary. The extent of waterlogging damage depends upon the duration of the perched water table and the depth of unsaturated soil above it. Traffic hardpans can develop in Herne sand at a depth of 10-20 cm (Smith et al. 1969), impeding root development and possibly accentuating any waterlogging.

Recommendations:

Suitability of Herne series soils for horticulture depends on the drainage status which varies, as explained previously. Drainage can be improved by mounding the topsoil and installing drains to remove excess water. With naturally adequate or improved drainage these soils are suitable for the production of wine grapes, dried vine fruit and, with good management, table grapes. Provided the drainage is adequate, then the soils are suitable for market gardening, citrus and stone fruit. Herne sand (deep phase) is marginally suitable for market gardening. High salinity of the irrigation water results in a leaching requirement to avoid salt build-up in the soil.

**Cruse series**

Description:

Yellowish brown duplex soils with a light textured A horizon. The surface soil is massive with a loamy sand to sandy loam texture overlying a yellowish brown, mottled medium clay. The Cruse series is similar to the Herne series, although it can also be a transitional soil between the Herne series and the alluvial soils (Pym 1955). As with the Herne series, the Cruse series has variable site drainage status, ranging from moderately well drained to imperfectly drained.

Limitations:

Drainage is the major limitation for irrigated viticulture on most areas of the Cruse series.

Recommendations:

The recommendations for the Cruse series generally follow those for the Herne series. Drainage may be necessary in some areas, otherwise the soils are suitable for all forms of viticulture. Cruse clay loam has a greater water-holding capacity and nutrient status, although it is not as easily cultivated as the lighter textured soils. The deeper, well drained Cruse series would be suitable for tree crops.
while the soils with light textured A horizons could be used for market gardening.

Swan series
Description:
Alluvial soils situated on the general level of the Swan Coastal Plain. Distinguishing features are the well developed B horizons and their red colour (Pym 1955). The sand fraction is micaceous.

Swan sand; Reddish brown duplex soils with a deep loamy sand A horizon.
Swan sandy loam to clay loam; Brown to red duplex or gradational soils. The topsoil has a sandy loam to clay loam texture with a massive structure and is about 15 cm thick. The subsoil texture varies from a clay loam to a medium clay and has an earthy fabric.

Limitations:
A minor limitation on the flat areas is slightly impeded drainage through the subsoil, otherwise excellent soils with desirable physical and chemical attributes.

Recommendations:
The Swan series are suitable for all the types of horticulture. The B horizon may impede the percolation of water to some extent with the development of a plough pan, although this condition can be readily reversed.

Belhus series
Description:
Soils formed on the older alluvium and which occur on the upper terraces; soil profiles are similar to the Houghton series, although B horizons are more developed. A typical profile is a dark brown loamy sand A1 horizon gradually increasing in texture to sandy clay loam at depth. These soils have a massive structure with an earthy fabric, and there is no restriction to root development.

Belhus series
Description:
Soils formed on the older alluvium and which occur on the upper terraces; soil profiles are similar to the Houghton series, although B horizons are more developed. A typical profile is a dark brown loamy sand A1 horizon gradually increasing in texture to sandy clay loam at depth. These soils have a massive structure with an earthy fabric, and there is no restriction to root development.

Houghton series
Description:
Soils formed on the older alluvium and which occur on the first terrace are mixed with the Belhus series on the higher levels (Pym 1955). A typical profile is a uniform yellowish red, micaceous sand to loamy sand with a massive structure. These are deep soils with no restriction to root development.

Limitations:
These soils have excellent physical and chemical characteristics with only minor limitations. They are slightly excessively drained (Pym 1955) and a hardpan can develop in these soils at about 20 cm.

Recommendations:
These soils have excellent physical and chemical characteristics, although internal drainage is slightly excessive. This can be overcome with good irrigation management and causes no limitation. Highly suitable for table grapes, stone fruit, citrus and wine grape production. These soils are too fertile for dried vine fruit production and the berries tend to be watery and of poor quality.

Pyorton series
Description:
Recent alluvial soils formed on the floodplain of the Swan River; soil profiles are highly variable and consist of bands of alluvium, often with a high coarse sand content. These are fertile soils with medium to heavy surface textures (loam, clay loam, clay), except for Pyorton sand. The latter is a result of a recent deposit of coarse alluvium over a Pyorton loam to clay loam (Pym 1955).

Limitations:
The flooding hazard is the main limitation and these soils can only be cultivated over a narrow moisture range. Consequently, correct timing of operations is imperative.

Recommendations:
The Pyorton series is generally suitable for table grapes, wine
grapes and dried vine fruit. Other forms of horticulture, except for summer market gardening, are precluded by the flooding hazard.

**Karrakatta series**

Description:

Deep uniform sands of aeolian origin, these soils are well to rapidly drained and predominantly occur as low rises on the western side of the Swan River. A profile typically consists of grey sand with organic matter (0-30 cm) over yellow sand.

Phases: Karrakatta sand (grey phase); Light grey A2 horizon to 0.5-1.0 m over yellow sand.

Limitations:

Moisture holding capacity and the low nutrient retention are the main limitations of these deep sandy soils. They are also highly wind erodible, particularly if in an exposed situation. The Karrakatta sand (grey phase) is less fertile and has a lower water-holding capacity.

Recommendations:

Karrakatta sand is marginally suitable for table grape and wine grape production, while the grey phase is not suitable. Provided there is a plentiful supply of groundwater, the Karrakatta sand can be quite productive for citrus, stone fruit and market gardening. The lower nutrient status and water-holding capacity of the Karrakatta sand (grey phase) results in it not being suitable for citrus production and only marginally suitable for stone fruit and market gardening.
Discussion

Adoption of new technology (such as link trellis), and production of varieties demanded by consumers, are important considerations if the table grape industry in the Swan Valley is to remain viable.

Viticulture is the most important industry in the Swan Valley and it is anticipated that it will maintain its importance. Research, extension and development need to be encouraged to continue improving the viability of viticulture and its competitiveness. An expansion of the citrus industry is not anticipated because large areas of citrus are being planted elsewhere on the Swan Coastal Plain and on the Dandaragan Plateau to the north. However, there is a place for low-chill stone fruit in the Swan Valley within the corridor of horticultural soils. Market gardening will continue, predominantly as a supplementary source of income for vignerons. Stone fruit and market gardening both have irrigation crop factors in the order of two to three times that for table grapes, which may limit their expansion in an area with limited groundwater supplies.

The land capability assessment shows a corridor of suitable horticultural land in the Swan Valley, flanked in the east by poorly drained Mongin soils and to the west by aeolian soils. On the foothills of the Darling Scarp the soils are generally suitable for viticulture, particularly wine grapes, although the scarcity of groundwater and wind exposure limit the development potential for table grapes. The deep, rapidly drained aeolian sands are suitable for market gardening, citrus and low chill stone fruit and marginally suitable for viticulture. Those aeolian soils found in low lying poorly drained areas are not suitable for horticulture. It is unlikely that large scale horticulture development will take place on the aeolian soils because the groundwater is primarily reserved for future public water supply (Gnangara Mound). Potential problems with fertilizer pollution of the groundwater may arise in addition to competition with urban land use.

The alluvial soils of the Swan Valley (Swan, Bellhus, Houghton soil series (Pym 1955), plus most of the Herne and Cruse soil series of the plain, are highly productive horticultural soils because of their physical and chemical characteristics. These soils are a scarce resource in Western Australia and are of particular value because of their location close to Perth. Most of the soils within the Swan Valley Rural Zone have a capability rating of Class I to Class III for horticulture.

Prime agricultural land

The State Planning Commission’s ‘Rural Land Use Planning Policy’ includes the requirement to discourage the removal of prime agricultural land from agricultural production and to prevent adverse effects on the viability of established agricultural industries (Anon. 1988).

Prime agricultural land in Western Australia may be defined as “that land which occurs where the agronomic factors (e.g. soils and management) and environmental factors (e.g. climate, water quality and availability) combine so that the ‘value to society’ from agriculture is greater than the value from alternative uses of the land” (Read 1988).

The value of land to society comprises both monetary and external values. The value of agricultural land includes its significance...
for the continuity of supply of a product to domestic and export markets (Read 1988).

The Swan Valley can be considered prime agricultural land because:

1. The Swan Valley is a proven area with respect to climate and soils for the production of premium quality table grapes and is the major production area for table grapes in Western Australia, supplying 95-99% of the domestic market, in addition to exports worth $0.5 million annually.

2. We believe the value to society of the viticulture industry in the Swan Valley goes beyond its direct economic value. The area is an important tourist, recreational and heritage area. It is a popular destination for day trips from Perth and much of its charm lies in the aesthetic rural setting provided by the vineyards.

Future land use implications

The area of prime agricultural land in the Swan Valley is about 3400 ha, which is sufficient to form the basis of a viable and expanding viticultural industry. However, competing and conflicting land use demands have the potential to erode the viability of the horticultural industry unless adequate land use and subdivisional controls are maintained. There is a need to accept the Swan Valley Rural Zone as a special horticultural area with a set of explicit policies dealing with appropriate and inappropriate land uses. The Swan Valley Rural Zone referred to here generally includes most of the prime agricultural land for table grape production, so the present Swan Valley Rural Zone boundaries are appropriate. Renaming the Swan Valley Rural Zone as a ‘special horticultural zone’ would facilitate its recognition as a special purpose zone. Land use control, if table grape production is to be promoted within this horticultural zone, needs to be more stringent than at present. A strict water allocation policy may be one means of achieving this goal.

In the Shire of Swan’s Town Planning Scheme No. 9 (Section 8.2.2) the term ‘prime agricultural land’, previously referred to as high quality horticultural soils, should now refer to land which is suitable for horticulture, comprising classes I-III as determined by the authors (Figure 8). It includes the Swan, Belhus, Houghton, Pyrton, Herne and Cruse soil series (Pym 1955).

‘Land not considered suitable for horticultural use’, refers to land with a Class IV and/or Class V capability rating for most horticultural crops (i.e. the area not shaded in Figure 8).

Within the horticultural zone, horticultural pursuits, particularly viticulture, should be encouraged on the Class I-III soils. Incentives should be given to maintain the viticultural industry already present and to encourage its expansion. The incentives already used, such as promotion, inspection, additional research staff and introduction of new table grape varieties has given the viticultural industry impetus to expand. Other incentives that have been made available, such as the preferential rating system, power cost concessions and ensuring adequate water supplies, improve the viability of viticulture.

On soil types Class IV to V, but still within the horticultural zone, alternative agricultural practices should be encouraged, provided that neither the use nor potential use of adjacent Class I, II and III soils nor the rural character and amenity of the area is adversely affected. Alternatively, on these Class IV and V soil types tourism, recreation and cottage industries use should be allowed where such uses have the potential to enhance and add to the purpose of the horticultural zone.

If land east of the standard gauge railway and west of West Swan Road is to be zoned urban as proposed in the review of the Corridor Plan for Perth (Anon. 1987), then significant buffer zones of low intensity rural-residential development are essential to reduce the speculative development pressure on the horticultural zone. Buffer zones of 0.5-1 km wide, would be adequate to minimize the development pressure within the relatively small and narrow horticultural zone. A narrow corridor of rural-residential use would also

High quality clay, a scarce natural resource, is found in the Swan Valley where a competing land use is the clay extraction industry. However, this industry is not compatible with all other land uses in the Swan Valley.
Figure 8. Location of the Swan Valley Rural Zone in relation to prime horticultural land for table grape production (Class I, II, III)
reduce potential conflicts and off-site impacts (dust, spray drift) between land uses.

There are still viable viticultural and horticultural enterprises existing outside the horticultural zone and within the rural living zone. The presence of these enterprises reduces the pressure on the horticultural zone because, in effect, it makes the horticultural zone seem larger. For this reason it is important to maintain these enterprises. If they are subject to the same incentives and concessions to those in the horticultural zone, it will help maintain viability and relieve pressure on the horticultural zone.

The authors believe that the area just outside the horticultural zone, but within the rural living zone, would be ideal for the development of tourism and recreational pursuits. Permission should only be given to those pursuits that add to the rural character of the Swan Valley.

There is limited prime horticultural land east of the railway line, but there are pockets of suitable soils, particularly for wine grapes. The better soil types are the Oakover and Lotons soil series (Pym 1955). Existing commercially viable vineyards on such foothill soils should be protected for horticulture by an appropriate zoning and separated from future urban development by rural-residential buffers, as described.

A subject for further discussion is clay excavation, which is not compatible with the maintenance of prime agricultural soils or with horticulture in the horticultural zone. It is generally not compatible with other uses in the Swan Valley, such as tourism. The Department of Agriculture is conducting research on the success of clay mine site rehabilitation for viticulture. Clay excavation could be considered in the rural-residential zone. If clay excavation is carried out in this area then the land should be rehabilitated to a standard appropriate to support urban and rural-residential uses.

With zoning, horticulture and particularly the viticultural industry will be in a better position to remain, and expand. With good planning, tourism and recreational pursuits can also be developed. With some control, the recreational and tourism pursuits will add to the character of the Swan Valley. In addition, there will be a place for rural and residential living.
Acknowledgements

The authors thank: Mr I. Cameron, Senior Technical Officer with the Department of Agriculture, for assisting with the determination of the land capability ratings. Staff from the Division of Horticulture and Division of Resource Management for constructive criticism of the manuscript, in particular Ms R. Oma. Mr R. Hulajko for technical assistance in the field and Mr R.A. Sommerville for preparation of the figures in this report. Mr G. Dimmock for providing access to detailed site data from the CSIRO Soil Archives. The GIS group of the Department of Agriculture for preparation of the maps and the Swan Valley Policy Committee for financially assisting the cost of map production.

The Cadastral base map used in Figures 2, 4, 7 and 8 is from the Department of Planning and Urban Development.


Malcolm, C.V. Western Australian Department of Agriculture file no. 2738/EX (unpublished).


Pym, L.W. (1955). Soils of the Swan Valley vineyard area. CSIRO Division of Soils. Soils and Land Use Series No. 20. 15


Webber, R.T.J. (1976a). The influence of climate and soil upon wine grape production and their importance in site selection. Proceedings of a seminar, Present status and future prospects held jointly by the University of Western Australia Country Extension Service and the Western Australian Department of Agriculture, Busselton, December 1976.

Webber, R.T.J. (1976b). Irrigation and drainage. Proceedings of a seminar, Present status and future prospects held jointly by the University of Western Australia Country Extension Service and the Western Australian Department of Agriculture, Busselton, December 1976.
### Existing land use

- **V** Viticulture
- **G** Grazing, hobby farming
- **O** Orchards
- **E** Extractive industries

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Land quality (No. of values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>Site drainage (6)</td>
</tr>
<tr>
<td>m</td>
<td>Moisture holding capacity (6)</td>
</tr>
<tr>
<td>n</td>
<td>Nutrient availability (5)</td>
</tr>
<tr>
<td>r</td>
<td>Rooting conditions (5)</td>
</tr>
<tr>
<td>y</td>
<td>Salinity hazard (5)</td>
</tr>
<tr>
<td>f</td>
<td>Flood hazard (4)</td>
</tr>
<tr>
<td>q</td>
<td>Potential for mechanization (5)</td>
</tr>
<tr>
<td>k</td>
<td>Soil workability (3)</td>
</tr>
<tr>
<td>w</td>
<td>Wind erosion hazard (6)</td>
</tr>
<tr>
<td>e</td>
<td>Water erosion hazard (5)</td>
</tr>
<tr>
<td>s</td>
<td>Soil structural decline hazard (3)</td>
</tr>
</tbody>
</table>

### Abbreviations in Appendices 1, 3 and 4

#### Land capability ratings
- **I** Very high capability for the stated land use
- **II** High capability
- **III** Fair capability
- **IV** Low capability
- **V** No capability

The letters following the class symbol indicate the limiting land qualities. A range of capability values for a unit indicates variable soil types or landform within that unit. (The land capability classification system is explained in the methodology. The land use types are described in the land use requirements section.)
## Land capability classes

### Appendix 1.

### Table A1.1. Summary table with capability classifications for all map units

<table>
<thead>
<tr>
<th>Map unit</th>
<th>Description</th>
<th>Existing land use</th>
<th>Land use type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Table grapes</td>
<td>Wine grapes</td>
</tr>
<tr>
<td>Soils of the Swan Valley vineyard area, W.A. (Pym, 1955)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(A) Soils of the Darling Scarp Face</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rocky and skeletal</td>
<td>Type E (unnamed)</td>
<td>Shallow brown loam to clay loam over rock</td>
<td>G</td>
</tr>
<tr>
<td>Soils of the Swan Valley vineyard area, W.A. (Pym, 1955)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(B) Soils of the foothills</td>
<td>Lotons series</td>
<td>Well drained duplex soils with a gravelly sand A horizon</td>
<td>G,V</td>
</tr>
<tr>
<td></td>
<td>Range series</td>
<td>Gravelly, yellow mottled duplex soils</td>
<td>G,V</td>
</tr>
<tr>
<td></td>
<td>Range sand (shallow phase)</td>
<td>Subsoil encountered at approximately 5 cm</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>Range sand (deep phase)</td>
<td>Deep duplex soils with a sandy A horizon</td>
<td>G,V</td>
</tr>
<tr>
<td></td>
<td>Oakeover series</td>
<td>Red-brown, moderately well drained, duplex soils</td>
<td>G,V</td>
</tr>
<tr>
<td>(C) Soils of the Plain</td>
<td>Mongin series</td>
<td>Duplex soils with a light textured A horizon over a cemented, clay subsoil</td>
<td>G,V</td>
</tr>
<tr>
<td></td>
<td>Mongin sand (swampy phase)</td>
<td>The poorly drained areas of the Mongin series</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>Mongin sand (deep phase)</td>
<td>Light grey sand over clay at depth</td>
<td>G, (O)</td>
</tr>
<tr>
<td></td>
<td>Herne series</td>
<td>Yellow duplex soils with light textured A horizons</td>
<td>V,G</td>
</tr>
<tr>
<td></td>
<td>Herne sand (deep phase)</td>
<td>Light grey sand over clay at approximately 1 metre depth</td>
<td>G,V,O</td>
</tr>
<tr>
<td></td>
<td>Herne sand (brown phase)</td>
<td>Yellow duplex soils with a brown A horizon</td>
<td>V,G</td>
</tr>
<tr>
<td></td>
<td>Alluvial fan suite 1</td>
<td>Grey, gritty sand and mottled gritty clay</td>
<td>G,(V)</td>
</tr>
<tr>
<td></td>
<td>Alluvial fan suite 2</td>
<td>Brown layer of sand, sandy loam, clay and grit</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>Bellevue series</td>
<td>Poorly drained, yellow mottled duplex soils</td>
<td>G,E</td>
</tr>
<tr>
<td></td>
<td>Gilgai complex</td>
<td>Gilgai microrelief with soils similar to Bellevue series</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>Andrew series</td>
<td>Poorly drained, brown duplex soils</td>
<td>E</td>
</tr>
<tr>
<td></td>
<td>Cruse series</td>
<td>Yellowish brown duplex soils with a light textured A horizon</td>
<td>V,G</td>
</tr>
<tr>
<td></td>
<td>Drainage line complex</td>
<td>Wet complex soils</td>
<td>G</td>
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37 LAND RESOURCES SERIES No. 6
## Appendix 1. continued

<table>
<thead>
<tr>
<th>Map unit</th>
<th>Description</th>
<th>Existing land use</th>
<th>Land use type</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Table grapes</td>
<td>Wine grapes</td>
</tr>
<tr>
<td>Solonchak (unnamed)</td>
<td>Saline soils</td>
<td>—</td>
<td>Vy</td>
</tr>
<tr>
<td>Claypans</td>
<td>—</td>
<td>G</td>
<td>Vi</td>
</tr>
</tbody>
</table>

(D) Alluvial soils

| Swan sand                             | Reddish brown duplex soils with a micaceous sandy Al horizon | V,G,O I-Iliw   | I-Iw           | Iln         | III    | III         | III            | IIIs           |
| Swan sandy loam/clay loam             | Reddish brown duplex soils                         | V,G,O I-Ils     | I-Ils          | Iln         | II-III | III         | III            | IIIs           |
| Belhus sand                           | Dark brown loamy micaceous sand, texture becoming finer with depth | V,O I          | IIln           | I           | I      | I           | I              | I              |
| Houghton series                       | Deep, yellowish red micaceous sands                  | V,G,O IIImw     | IIImw          | II-IImn     | I      | II-IImm     | IV             | I              |
| Pyrton series                         | Recent alluvium with dark brown micaceous layers over sandy layers | G,V IIIf       | II-IIImn       | II-IImn     | Vf     | Vf          | IV-Vf          | IV-Vf          |
| Pyrton sand                           | Coarse sandy Al horizon                             | G                | III            | III-IVf     | IIIf   | IIIf         | III-Vf         | IVf            |

(E) Aeolian and miscellaneous soils

| Karrakatta sand                       | Deep, uniform yellow sands                         | G,(O,V) IIIm     | IIIm           | IVm         | IImn   | IImn        | IIm            | I              |
| Karrakatta sand (grey phase)          | Deep, light grey sand over yellow sand             | G                | IV-Vm          | IV-Vm       | IIImn   | II-IIIm     | III            | IIIq           |
| Muchea sand                           | Deep, light grey sands                              | G,(V) Vm         | Vm             | Vm          | IVmm    | IImn        | III-Vm         | III-Vm         |
| Barrett sand                          | Poorly drained light grey sands with organic hardpan B horizon | G                | Vi             | Vi          | Vi      | Vi          | Vi             | Vi             |
| Bibra sand                            | Poorly drained, light grey organic stained sands    | G                | Vi             | Vi          | Vi      | Vi          | Vi             | Vi             |

Environmental Geology Series, Muchea Sheet (1: 50 000)

| S10                                   | Rapidly drained, deep light grey sands              | IV-Vm            | Vm             | Vm          | IVmn    | IImn        | IIm            |
| S12                                   | Deep, uniform yellow sands                          | III-mw           | III-mw         | IVm         | II-IIIm  | IImn        | IIm            |
| MSG1                                  |                                                  | IIIr             | IIr            | IIIm         | IIIi    | IIIi        | IIr             |
## Table A2.1. Summary table of land qualities for all map units

<table>
<thead>
<tr>
<th>Map Unit</th>
<th>Site drainage</th>
<th>Moisture holding capacity</th>
<th>Nutrient retention</th>
<th>Rooting conditions</th>
<th>Salinity hazard</th>
<th>Flood hazard</th>
<th>Soil workability</th>
<th>Potential for mechanization</th>
<th>Wind erosion hazard</th>
<th>Water erosion hazard</th>
<th>Soil structural decline hazard</th>
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<tr>
<td></td>
<td>(i)</td>
<td>(m)</td>
<td>(n)</td>
<td>(r)</td>
<td>(s)</td>
<td>(f)</td>
<td>(k)</td>
<td>(q)</td>
<td>(w)</td>
<td>(e)</td>
<td>(s)</td>
</tr>
<tr>
<td>Soils of the Swan Valley vineyard area, W.A. (Pym, 1955)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rocky and skeletal</td>
<td>Low</td>
<td>Very low</td>
<td>Poor</td>
<td>Nil to low</td>
<td>High</td>
<td>Very low</td>
<td>Moderate</td>
<td>Very low</td>
<td>Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type E (unnamed)</td>
<td>Low</td>
<td>Very low</td>
<td>Poor to fair</td>
<td>Nil to low</td>
<td>Low</td>
<td>Very low</td>
<td>Moderate</td>
<td>Very low</td>
<td>Low</td>
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### Soil series and their characteristics

<table>
<thead>
<tr>
<th>Soil Series</th>
<th>Site drainage</th>
<th>Moisture holding capacity</th>
<th>Nutrient retention</th>
<th>Rooting conditions</th>
<th>Salinity hazard</th>
<th>Flood hazard</th>
<th>Soil workability</th>
<th>Potential for mechanization</th>
<th>Wind erosion hazard</th>
<th>Water erosion hazard</th>
<th>Soil structural decline hazard</th>
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</thead>
<tbody>
<tr>
<td>Egg...</td>
<td>Imperfectly drained</td>
<td>Moderately low</td>
<td>Very low to low</td>
<td>Poor to fair</td>
<td>Moderate to high</td>
<td>Nil to low</td>
<td>Moderate</td>
<td>Very high to high</td>
<td>High</td>
<td>Very low</td>
<td>Low</td>
</tr>
<tr>
<td>El...</td>
<td>Poorly drained</td>
<td>Low to Very low</td>
<td>Poor to fair</td>
<td>Nil to low</td>
<td>Moderate to high</td>
<td>Nil to low</td>
<td>Moderate</td>
<td>Very high to high</td>
<td>High</td>
<td>Very low</td>
<td>Low</td>
</tr>
<tr>
<td>El...</td>
<td>Imperfectly drained</td>
<td>Moderately low</td>
<td>Very low to low</td>
<td>Poor to fair</td>
<td>Moderate to high</td>
<td>Nil to low</td>
<td>Moderate</td>
<td>Very high to high</td>
<td>High</td>
<td>Very low</td>
<td>Low</td>
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<tr>
<td>El...</td>
<td>Moderately well to imperfectly drained</td>
<td>Low to Very low</td>
<td>Good to Very good</td>
<td>Nil to low</td>
<td>Nil to low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
<td>Moderate</td>
<td></td>
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<td>El...</td>
<td>Very low</td>
<td>Poor to fair</td>
<td>Nil to low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
<td>Moderate</td>
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<tr>
<td>El...</td>
<td>Imperfectly drained</td>
<td>Moderate</td>
<td>Very low to low</td>
<td>Good to Very good</td>
<td>Nil to low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>El...</td>
<td>Moderately well drained</td>
<td>Low to Moderate</td>
<td>Very low to low</td>
<td>Good to Very good</td>
<td>Nil to low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>El...</td>
<td>Very low</td>
<td>Poor to fair</td>
<td>Nil to low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>El...</td>
<td>Very low</td>
<td>Poor to fair</td>
<td>Nil to low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>El...</td>
<td>Very low</td>
<td>Poor to fair</td>
<td>Nil to low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>El...</td>
<td>Very low</td>
<td>Poor to fair</td>
<td>Nil to low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

39 LAND RESOURCES SERIES No. 6
<table>
<thead>
<tr>
<th>Map Unit</th>
<th>Site drainage</th>
<th>Moisture holding capacity</th>
<th>Nutrient retention conditions</th>
<th>Rooting</th>
<th>Salinity hazard</th>
<th>Flood hazard</th>
<th>Soil workability</th>
<th>Potential for mechanization</th>
<th>Wind erosion hazard</th>
<th>Water retention hazard</th>
<th>Soil structural decline hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bellevue series</td>
<td>Poorly drained</td>
<td>—</td>
<td>Poor to fair</td>
<td>—</td>
<td>Low to moderate</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Gilgai complex</td>
<td>Poorly drained</td>
<td>—</td>
<td>Fair</td>
<td>Moderate to high</td>
<td>Nil to very low</td>
<td>Moderate Moderate</td>
<td>Moderate to high</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Andrew series</td>
<td>Poorly drained</td>
<td>—</td>
<td>Poor to fair</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Cruse series</td>
<td>Moderately well to imperfectly drained</td>
<td>Moderate</td>
<td>Low to moderate</td>
<td>Good</td>
<td>Low to high</td>
<td>Nil to very low</td>
<td>Moderate</td>
<td>Very high to high</td>
<td>High</td>
<td>Very low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Drainage line complex</td>
<td>Poorly drained</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>High</td>
<td>Low to moderate</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Solonchak (unnamed)</td>
<td></td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Saline to highly saline</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Claypans</td>
<td>Poorly drained</td>
<td>—</td>
<td>Fair to poor</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

(D) Alluvial soils

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Drainage Condition</th>
<th>Moisture Holding Capacity</th>
<th>Nutrient Retention Conditions</th>
<th>Rooting</th>
<th>Salinity Hazard</th>
<th>Flood Hazard</th>
<th>Workability</th>
<th>Potential for Mechanization</th>
<th>Wind Erosion Hazard</th>
<th>Water Retention Hazard</th>
<th>Structural Decline Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swan sand</td>
<td>Moderately well to well drained</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Excellent</td>
<td>Nil to very low</td>
<td>Nil to very low</td>
<td>High</td>
<td>Very high</td>
<td>Moderate</td>
<td>Very low</td>
<td>Low to moderate</td>
</tr>
<tr>
<td>Swan sandy loam/clay loam</td>
<td>Moderately well to well drained</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Excellent</td>
<td>Nil to very low</td>
<td>Nil to very low</td>
<td>High</td>
<td>Very high</td>
<td>Low to moderate</td>
<td>Moderate</td>
<td>Very low</td>
</tr>
<tr>
<td>Belhus sand</td>
<td>Well drained</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Excellent</td>
<td>Nil to very low</td>
<td>Nil to very low</td>
<td>High</td>
<td>Very high</td>
<td>Moderate</td>
<td>Very low</td>
<td>Low</td>
</tr>
<tr>
<td>Houghton series</td>
<td>Well drained</td>
<td>Moderate</td>
<td>Low to moderate</td>
<td>Excellent</td>
<td>Nil to very low</td>
<td>Nil to very low</td>
<td>High</td>
<td>Very high</td>
<td>High</td>
<td>Very low</td>
<td>Low</td>
</tr>
<tr>
<td>Pyrton series</td>
<td>Moderately well to well drained</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Excellent</td>
<td>Nil to very low</td>
<td>Moderate to high</td>
<td>Low</td>
<td>Very high</td>
<td>Moderate</td>
<td>Very low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Pyrton sand</td>
<td>Well drained</td>
<td>Moderate</td>
<td>Low</td>
<td>Excellent</td>
<td>Nil to very low</td>
<td>High</td>
<td>Moderate</td>
<td>Very high</td>
<td>Low to moderate</td>
<td>Very low</td>
<td>Low</td>
</tr>
<tr>
<td>Map Unit S ite Moisture Nutrient Rooting Salinity Flood Soil Potential Wind Water Soil</td>
<td>(i)</td>
<td>(m)</td>
<td>(n)</td>
<td>(r)</td>
<td>(y)</td>
<td>(f)</td>
<td>(k)</td>
<td>(q)</td>
<td>(w)</td>
<td>(e)</td>
<td>(s)</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
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<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>(E) Aeolian and miscellaneous soils</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Karrakatta sand</td>
<td>Well to rapidly drained</td>
<td>Low</td>
<td>Very low</td>
<td>Excellent</td>
<td>Nil to very low</td>
<td>Nil to very low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
<td>Low</td>
</tr>
<tr>
<td>Karrakatta sand (grey phase)</td>
<td>Rapidly drained</td>
<td>Very low to low</td>
<td>Very low</td>
<td>Excellent to extremely low</td>
<td>Nil to very low</td>
<td>Nil to very low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
<td>Low</td>
</tr>
<tr>
<td>Muchea sand</td>
<td>Rapidly drained</td>
<td>Very low to low</td>
<td>Extremely low</td>
<td>Very low</td>
<td>Moderate</td>
<td>Nil to very low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
<td>Low</td>
</tr>
<tr>
<td>Barrett sand</td>
<td>Poorly drained</td>
<td>Low</td>
<td>Very low</td>
<td>Extremely low</td>
<td>Good</td>
<td>High</td>
<td>Nil to very low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
</tr>
<tr>
<td>Bibra sand</td>
<td>Poorly drained</td>
<td>Low</td>
<td>Very low</td>
<td>Extremely low</td>
<td>Good</td>
<td>High</td>
<td>Nil to very low</td>
<td>Moderate</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low to high</td>
</tr>
<tr>
<td>Env. Geology 1 : 50 000 Series, Muchea Sheet.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10</td>
<td>Rapidly drained</td>
<td>Very low</td>
<td>Extremely low</td>
<td>Excellent</td>
<td>Nil to very low</td>
<td>Nil to very low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
<td>Low</td>
</tr>
<tr>
<td>S12 (Yellow sand)</td>
<td>Well to rapidly drained</td>
<td>Moderately low to low</td>
<td>Very low</td>
<td>Excellent</td>
<td>Nil to very low</td>
<td>Nil to very low</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
<td>Low</td>
</tr>
<tr>
<td>Msgl</td>
<td>Moderately well drained</td>
<td>Moderate</td>
<td>Low</td>
<td>Good to very good</td>
<td>Nil to very low</td>
<td>Nil to very low</td>
<td>High</td>
<td>Very high</td>
<td>Moderate</td>
<td>Very low</td>
<td>Low</td>
</tr>
</tbody>
</table>
Land quality descriptions and values

Appendix 3.

The following descriptions of each land quality are derived from Moore (1990). The tables describe the values for each land quality. The number of values for each land quality varies from three to six. The lower numbered values generally being more favourable for plant growth.

### Table A3.1. Site drainage (i)

<table>
<thead>
<tr>
<th>Value</th>
<th>Numerical rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very poorly drained</td>
<td>6</td>
<td>Water is removed from the soil so slowly that the water table remains at or near the surface for most of the year.</td>
</tr>
<tr>
<td>Poorly drained</td>
<td>5</td>
<td>Water is removed very slowly in relation to supply. All horizons remain waterlogged for periods of several months.</td>
</tr>
<tr>
<td>Imperfectly drained</td>
<td>4</td>
<td>Water is removed only slowly in relation to supply. Some horizons may be mottled and/or have orange or rusty linings of root channels, and are waterlogged for periods of several weeks.</td>
</tr>
<tr>
<td>Moderately well drained</td>
<td>3</td>
<td>Water is removed from the soil somewhat slowly in relation to supply, because of low permeability, shallow water table, lack of gradient, or some combination of these. Some horizons may remain waterlogged for as long as one week after addition of water.</td>
</tr>
<tr>
<td>Well drained</td>
<td>2</td>
<td>Water is removed from the soil readily, but not rapidly. Some horizons may remain waterlogged for several days after addition of water.</td>
</tr>
<tr>
<td>Rapidly drained</td>
<td>1</td>
<td>Water is removed from the soil rapidly in relation to supply. No horizon is normally waterlogged/wet for more than several hours after addition of water.</td>
</tr>
</tbody>
</table>

#### 3.1 Site drainage (i)

The land quality, site drainage (waterlogging), refers to the overall site and internal soil drainage. Drainage is influenced by internal factors including soil texture, structure, water-holding capacity, the presence of an impermeable layer, the depth to this layer if present and external factors including the slope and the amount of run-on.

For irrigated horticulture, a well drained site is a major priority. Soils which are naturally well drained have an added advantage for horticulture with a low proliferation of root diseases and soil borne pathogens. If the drainage in an area is a limiting factor then surface and sub-surface drains may be installed. The feasibility of installing drains to alleviate a waterlogging problem is determined by the soil type and whether there is anywhere to drain the water. The capability ratings assume no additional drainage has been installed.

The feasibility of installing drains was not included, because it is not an inherent characteristic of the map unit. Consequently an area which has a marginal capability due to a waterlogging constraint may or may not be readily drained.
### Table A3.2. Moisture holding capacity (m)

<table>
<thead>
<tr>
<th>Value</th>
<th>Numerical rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>6</td>
<td>Moderately deep to deep soils with a very low available water capacity* (AWC) of &lt; 20 mm H₂O/m. Alternatively, soils in which the moisture availability is restricted by the shallow effective rooting depth. Soil types include coarse, uniform sands (e.g. Bassendean series) and skeletal soils.</td>
</tr>
<tr>
<td>Low</td>
<td>5</td>
<td>Moderately deep to deep soils with a low AWC of 20-50 mm H₂O/m. In addition, soils with restricted moisture availability because of moderately shallow rooting conditions. Soil types include uniform sands with an earthy fabric, or minor clay content (e.g. Karrakatta sand (yellow phase)) and shallow, sandy duplex soils.</td>
</tr>
<tr>
<td>Moderately low</td>
<td>4</td>
<td>Moderately deep to deep soils with an AWC of 50-80 mm H₂O/m. Also moderately shallow soils with a moderate AWC. Soil types include uniform fine sands and moderately deep, sandy duplex soils.</td>
</tr>
<tr>
<td>Moderate</td>
<td>3</td>
<td>Moderately deep to deep soils with an AWC of about 120 mm H₂O/m. Soil types include uniform sandy loams and duplex soils with medium textured A horizons (e.g. Herne sandy loam).</td>
</tr>
<tr>
<td>Moderately high</td>
<td>2</td>
<td>Moderately deep to deep soils with an AWC of about 160 mm H₂O/m. Soil types include duplex soils with medium textured topsoils overlying well structured or earthy B horizons (e.g. Swan sandy loam).</td>
</tr>
<tr>
<td>High</td>
<td>1</td>
<td>Deep to very deep soils with an AWC probably &gt; 160 mm H₂O/m. Soil types include deep, uniform loams (e.g. Pyrton loam) and deep, gradational soils.</td>
</tr>
</tbody>
</table>

* Available water capacity (AWC) is the difference between the amount of water held at field capacity and the amount held at permanent wilting point.

### 3.2 Moisture holding capacity (m)

The land quality, moisture holding capacity, is closely related to the available water capacity (AWC). The AWC is the amount of water held in the soil between field capacity and permanent wilting point. The moisture holding capacity is mainly a function of the soil texture and the effective soil depth (Appendix 3.4). On some soil types deep-rooted plants have an advantage over shallow-rooted plants and are able to extract more water from the profile. Moisture holding capacity is only a significant limitation for most horticultural crops when the AWC is extremely low. Otherwise, differences in the AWC only affect the frequency of irrigation scheduling. On soils with an extremely low AWC crops may suffer moisture stress under high evaporative demand conditions even if the crop is irrigated two or three times a day. These soils also have higher irrigation requirements.
Table A3.3. Nutrient availability (n)

<table>
<thead>
<tr>
<th>Value</th>
<th>Numerical rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely low</td>
<td>5</td>
<td>Soils are inherently of low fertility and may have gross deficiencies of the major elements. The cation exchange capacity (CEC) in the surface 20 cm is probably &lt; 3 meq/100 g, and applied nutrients are readily leached down the profile. Soil types are highly leached, pale or bleached deep sands (e.g. Gavin series of the Bassendean Sand).</td>
</tr>
<tr>
<td>Very low</td>
<td>4</td>
<td>Soils with a very low nutrient availability. These soils would have an inherently low natural fertility and there would be some leaching of applied nutrients. The CEC would normally be in the range 3-6 meq/100 g. Soil types include deeper sandy duplex soils where the clay subsoil is &gt; 30 cm and deep sands with high organic matter content (e.g. Joel series of the Bassendean sands) and some soils of the Spearwood and Quindalup series.</td>
</tr>
<tr>
<td>Low</td>
<td>3</td>
<td>Soils with a low natural fertility and regular fertilizer applications are necessary. There would be some leaching of applied nutrients out of the topsoil and/or fixing may take place. The CEC is probably in the range 6-12 meq/100 g. Soil types include duplex soils with bleached A2 horizons and Spearwood and Quindalup series.</td>
</tr>
<tr>
<td>Moderate</td>
<td>2</td>
<td>Soils are naturally more fertile although regular fertilizer applications would be necessary if the soils are used for annual crops. The CEC would be in the range 12-20 meq/100 g and there would not be any extremes of pH or Fe₂O₃ content. Soil types include red, yellow and brown duplex soils and gradational earths.</td>
</tr>
<tr>
<td>High</td>
<td>1</td>
<td>Soils are highly fertile and only infrequent applications of fertilizer would be necessary. The CEC is &gt; 20 meq/100 g, the pH is neutral and there is only a low Fe₂O₃ content. Soil types in this category are rare in Australia. The only soils to fit this class within the study are certain recent alluvial soils (e.g. Pynton loam).</td>
</tr>
</tbody>
</table>

3.3 Nutrient availability (n)

The nutrient availability of soils depends upon soil characteristics including soil texture, cation exchange capacity, the organic matter content and the pH. Soils with a low exchange capacity which are readily leached and soils with high fixing capacities are naturally low in available nutrients.

For intensive horticulture (i.e. market gardening), the copious amounts of fertilizer applied and the relatively low cost of fertilizer compared with other production costs negates the need to use naturally fertile soils. The relative importance of nutrient availability increases with the generally less intensive perennial crops (i.e. viticulture, stone fruit).
Table A3.4. Rooting conditions \( r \)

<table>
<thead>
<tr>
<th>Value</th>
<th>Numerical rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>5</td>
<td>Shallow soils with an effective soil depth (&lt; 0.2 \text{ m}). Alternatively the soils are moderately shallow ((0.2-0.5 \text{ m})) with a high ((&gt; 50%)) gravel/stone content. Soil types include skeletal soils over bedrock and some very poorly drained soils.</td>
</tr>
<tr>
<td>Fair</td>
<td>4</td>
<td>Moderately shallow soils with an effective soil depth from (0.2-0.5 \text{ m}). Alternatively the soils are moderately deep ((0.5-1.0 \text{ m})) with a high ((&gt; 50%)) gravel stone content. Soil types include duplex soils with a massive, impermeable B horizon.</td>
</tr>
<tr>
<td>Good</td>
<td>3</td>
<td>Moderately deep soils with an effective soil depth from (0.5-1.0 \text{ m}). Alternatively the soils are deep ((&gt; 1.0 \text{ m})) with a high ((&gt; 50%)) gravel/stone content. Soil types include gravelly duplex soils and duplex soils with well structured subsoils.</td>
</tr>
<tr>
<td>Very good</td>
<td>2</td>
<td>Deep soils with an effective soil depth between (1-2 \text{ m}). Soil types include the transitional soils between the deep, sandy duplex soils and the uniform sands.</td>
</tr>
<tr>
<td>Excellent</td>
<td>1</td>
<td>Very deep soils with an effective soil depth (&gt; 2 \text{ m}). Soil types include uniform sands and gradational earths.</td>
</tr>
</tbody>
</table>

3.4 Rooting conditions \( r \)

Rooting conditions refers specifically to root room and mechanical impedance. Root room is the soil volume available for root growth and is predominantly a function of the effective soil depth, porosity and pore size distribution and content of coarse fragments. Gravels and stone in the soil profile reduce the soil volume in proportion to their abundance. The effective soil depth is the depth to an impenetrable barrier such as rock, a cemented ironstone pan or a dense, massive clay subsoil. A perched or permanent water table can also act as a barrier to root development. For this study an impenetrable layer is deemed to be any layer which impedes the development of the majority of the roots.
### Table A3.5. Salinity hazard (y)

<table>
<thead>
<tr>
<th>Value</th>
<th>Numerical rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly saline</td>
<td>5</td>
<td>Areas which are presently highly saline, with a surface (0-0.2 m) soil salinity level greater than 1200 µS/cm. Ground cover is likely to be absent or a sparse cover of highly salt tolerant species. There is likely to be a saline water table within one metre of the surface.</td>
</tr>
<tr>
<td>Saline</td>
<td>4</td>
<td>Areas which are presently saline, with a surface (0-0.2 m) soil salinity level 600-1200 µS/cm. Pastures would be dominated by sea barley grass (<em>Hordeum maritinum</em>) with an absence of clovers. The water table is likely to be within 2 m of the surface.</td>
</tr>
<tr>
<td>(High salinity hazard)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-saline</td>
<td>3</td>
<td>Areas which are presently non-saline, although there is a high risk of salinity developing if they are irrigated. The surface (0-0.2 m) soil salinity level is &lt; 600 µS/cm, although the water table may be within 1 to 2 metres of the surface.</td>
</tr>
<tr>
<td>(Moderate salinity hazard)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-saline</td>
<td>2</td>
<td>Areas which are presently non-saline, although there is a moderate risk of salinity developing if they are irrigated. The water table may be about 2 m below the surface.</td>
</tr>
<tr>
<td>(Nil to low salinity hazard)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-saline</td>
<td>1</td>
<td>Areas which are presently non-saline and the likelihood of salinity developing, if irrigated, is slight.</td>
</tr>
</tbody>
</table>

### 3.5 Salinity hazard (y)

Salinity is caused by high water tables with the capillary rise of groundwater into the root zone and the subsequent concentration of salt at or close to the surface through evapotranspiration. Existing salinity can be detected through a soil test or inferred from the vegetation type, while in severe cases white crystalline salt may be visible on the soil surface. Any land which already shows symptoms of salinity should not be considered for horticulture. In areas which are presently non-saline, the salinity hazard under irrigation is difficult to determine. It can be related to the level of any existing water tables, the permeability of the soil and the salt storage in the soil profile. The Bibra sand of the Badseandean association is subject to high water tables during the winter months, although the likelihood of salinity developing is low. This is because of the highly permeable nature of the soil and the very low levels of salt stored in the profile.
3.6 Flood hazard (f)

Flooding is a temporary condition because of excessive run-off following heavy rainfall events and usually involves moving water. It may be differentiated from waterlogging, which can include ponded water because of high water tables. Flooding may also involve physical damage, with crops being flattened and erosion damage through the removal of topsoil. Horticultural crops vary in their tolerance to flooding, while the timing of any flood is also critical. Grapevines are fairly tolerant of flooding during their dormant phase over winter, although considerably less tolerant during spring. Many perennial crops have a productive lifespan of 10-30 years, therefore even infrequent floods (1:10 years or less frequent) are likely to occur within the lifespan of the crop.

3.7 Potential for mechanization (q)

The land quality potential for mechanization refers to land features which directly help or hinder mechanized agricultural operations. Hindrances include surface rocks, rock outcrop, gilgai microrelief and excessive slope. This land quality is distinct from 'soil workability' which refers to the ease of cultivation.

Table A3.6. Flood hazard (f)

<table>
<thead>
<tr>
<th>Value</th>
<th>Numerical rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>4</td>
<td>Frequent, physically damaging or prolonged floods. The flood return period is less than one year.</td>
</tr>
<tr>
<td>Moderate</td>
<td>3</td>
<td>Fairly frequent, physically damaging or prolonged floods. The flood return period is one year to ten years.</td>
</tr>
<tr>
<td>Low</td>
<td>2</td>
<td>Infrequent, physically damaging or prolonged floods. The flood return period is ten years to 100 years.</td>
</tr>
<tr>
<td>Nil to very low</td>
<td>1</td>
<td>Negligible flood hazard; either not subject to flooding or the flood return period is &gt; 100 years.</td>
</tr>
</tbody>
</table>

Table A3.7. Potential for mechanization (q)

<table>
<thead>
<tr>
<th>Value</th>
<th>Numerical rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>5</td>
<td>Either excessive slopes (&gt; 25%), or the abundance of rock outcrop (&gt; 15%) prohibit mechanization.</td>
</tr>
<tr>
<td>Low</td>
<td>4</td>
<td>Low potential for mechanization because of moderately steep slopes (15-25%), the abundance of rock outcrop (10-15%), or a combination of the two. Alternatively, on flat to gently sloping land, dense gilgai microrelief can severely restrict mechanization.</td>
</tr>
<tr>
<td>Moderate</td>
<td>3</td>
<td>Moderate potential for mechanization because of slope (10-15%), the abundance of rock outcrop (1-10%), or a combination of the two. On flat to gently sloping land, dense shallow gilgai microrelief can restrict mechanization.</td>
</tr>
<tr>
<td>High</td>
<td>2</td>
<td>Slight restriction to mechanization because of slope (5-10%), or scattered gilgai microrelief.</td>
</tr>
<tr>
<td>Very high</td>
<td>1</td>
<td>Flat to gently sloping land (0-5%), rock outcrop and gilgai microrelief are absent.</td>
</tr>
</tbody>
</table>
Table A3.8. Soil workability (k)

<table>
<thead>
<tr>
<th>Value</th>
<th>Numerical rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>3</td>
<td>Soil factors greatly restrict cultivation and these soils can only be cultivated satisfactorily over a narrow moisture range. When dry, the soil is too hard to work and tends to get excessively boggy for long periods in winter. These soils may be poorly or very poorly drained and/or the heavy textured surface soils are massive and hard-setting.</td>
</tr>
<tr>
<td>Moderate</td>
<td>2</td>
<td>Soil factors restrict cultivation in most years to some extent and there will be periods in winter when the soil is boggy. Surface soils are usually medium textured with a firm surface soil condition. Site drainage is poorly drained to moderately well drained.</td>
</tr>
<tr>
<td>High</td>
<td>1</td>
<td>Under normal conditions soil factors rarely restrict cultivation. The soil can be worked over a wide moisture range and can normally be worked within 72 hours of significant rainfall. Surface soils are usually light textured (Texture groups 1 and 2) with a single grain structure, or massive with a soft surface soil condition. Soils would normally be moderately well drained to rapidly drained.</td>
</tr>
</tbody>
</table>

3.8 Soil workability (k)

Soil workability is the ease with which a soil can be tilled. The workability of a soil depends on a number of interrelated soil characteristics including texture, structure, organic matter content, hard-setting nature and the amount of gravel or stone in the surface layer.
### 3.9 Wind erosion hazard (w)

Wind erosion hazard refers to the ease with which soil particles are detached and transported from land surfaces by the action of the wind. Transport of wind-blown particles can occur through saltation, suspension or surface creep (Bagnold 1941). Wind erosion hazard is a combination of climatic, landform and soil factors. Climatic factors include the frequency, strength and direction of erosive winds (wind speed > 30 km/h). Landform, including aspect, is a major determinant of exposure. Soil factors include the surface condition, surface structure and texture, particularly the fine sand component.

In general, wind erosion is not a major problem for horticultural land uses. Annual crops tend to be more susceptible than perennial crops. For annual crops, the wind erosion hazard is highest during the preparation of the soil before planting and at the seedling stage when the canopy cover is low. Significant production losses can occur through crop sand-blasting. Control is through windbreaks and the application of additional irrigation to maintain the moisture content of the surface soil. With the development of improved irrigation systems to reduce watering rates, windbreaks may be the preferred option.

#### Table A3.9. Wind erosion hazard (w)

<table>
<thead>
<tr>
<th>Value</th>
<th>Numerical rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>5</td>
<td>Highly erodible soils in moderate to highly exposed positions:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The soils are uniform sands with a single grain structure and a loose surface condition. The sand</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fraction is medium to fine. Soil types include dune sands and deep sands on a plain (e.g.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gavin sand and Karrakatta sand).</td>
</tr>
<tr>
<td>High</td>
<td>4</td>
<td>Moderately to highly erodible soils:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Surface soils have a single grain structure and may be loose with a coarse sand fraction, or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>have a surface crust and a predominantly fine sand fraction. Surface soil textures are generally</td>
</tr>
<tr>
<td></td>
<td></td>
<td>light; sands to loamy sands. Soil types include uniform deep sands and duplex soils (e.g. Houghton</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sand, Herne series).</td>
</tr>
<tr>
<td>Moderate</td>
<td>3</td>
<td>Soil types with a moderate erodibility:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>There is a wide range of soils in this category including light textured soils (sands to loamy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sands) with a massive to weekly ped surface structure and a soft to firm surface condition when</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dry. Also, sandy soils with a significant surface gravel component and self-mulching days with</td>
</tr>
<tr>
<td></td>
<td></td>
<td>a loose surface condition and with an average ped size &lt; 1 mm. Examples include, Lotos series,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and Pyrton sand.</td>
</tr>
<tr>
<td>Moderately low</td>
<td>2</td>
<td>Soils with a moderately low erodibility:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil types include medium to heavy textured soils, except for those with a hard-setting surface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>condition. Also, hard-setting light textured soils. Examples include, Pyrton series.</td>
</tr>
<tr>
<td>Low</td>
<td>1</td>
<td>Soils with a low erodibility:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil types include hard-setting medium to heavy textured soils. Also, all soil types which are</td>
</tr>
<tr>
<td></td>
<td></td>
<td>very poorly drained (i.e. the surface remains moist to wet for the whole year). Examples include,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>swamp soils and Bellevue series.</td>
</tr>
</tbody>
</table>

**LAND RESOURCES SERIES No. 6**
Table A3.10. Water erosion hazard (e)

<table>
<thead>
<tr>
<th>Value</th>
<th>Numerical rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>5</td>
<td>Highly erodible* soils on slopes of 20-30%, together with any slopes &gt; 30%.</td>
</tr>
<tr>
<td>High</td>
<td>4</td>
<td>Highly erodible soils on slopes of 10-20%, or moderately erodible soils on slopes of 20-30%.</td>
</tr>
<tr>
<td>Moderate</td>
<td>3</td>
<td>Highly erodible soils on slopes of 3-10%, or moderately erodible soils on slopes of 10-20%, or soils of low erodibility on slopes of 20-30%.</td>
</tr>
<tr>
<td>Low</td>
<td>2</td>
<td>Highly erodible soils on slopes &lt;3%, or moderately erodible soils on slopes of 3-10%, or soils of low erodibility on slopes of 3-20%.</td>
</tr>
<tr>
<td>Very low</td>
<td>1</td>
<td>Low to moderately erodible soils on slopes &lt;3%.</td>
</tr>
</tbody>
</table>

* Soil erodibility: Is a function of the soil resistance to detachment and the rainfall acceptance rate in winter.

3.10 Water erosion hazard (e)

Water erosion is a process in which soil is detached and transported from the land by the action of rainfall, run-off and seepage. Common types of water erosion include sheet, rill, gully, stream bank and tunnel erosion (Houghton and Charman 1986). In the Swan Valley, water erosion is generally not a major constraint because of the low relief and high infiltration rates on the sandy soils. A simple classification based predominantly on slope has been used to assess the water erosion hazard.

Table A3.11. Soil structural decline hazard (s)

<table>
<thead>
<tr>
<th>Value</th>
<th>Numerical rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>3</td>
<td>Soil structure adversely affected under continued cultivation, resulting in substantial yield penalties. This situation is not easily reversed.</td>
</tr>
<tr>
<td>Moderate</td>
<td>2</td>
<td>Soil structure adversely affected under continued cultivation. This situation can be economically reversed. For example, the development of a traffic hardpan on duplex soils with light textured A horizons.</td>
</tr>
<tr>
<td>Nil-low</td>
<td>1</td>
<td>Soil structure suffers nil to minor degradation under continued cultivation. Any yield losses are small and would not offset costs of treatment. Surface soils are usually single grained or highly pedal (self-mulching).</td>
</tr>
</tbody>
</table>

3.11 Soil structural decline hazard (s)

This land quality refers to the decline in the soil structure compared with the pristine state. It could take the form of surface slaking, development of a hard-setting surface, decrease in pedality or the development of a traffic hardpan. In the Swan Valley, traffic hardpans induced by machinery movement between the vine rows are quite common. The increase in the bulk density of the soil and decrease in permeability, especially under the wheel tracks, can exacerbate any waterlogging problems (Smith et al. 1969).
Land capability rating tables for each land use type

Appendix 4.

The following tables are to be read in conjunction with the land quality descriptions and values in the tables in Appendix 3.

Table A4.1. Land capability rating for table grapes

<table>
<thead>
<tr>
<th>Land quality*</th>
<th>I</th>
<th>II</th>
<th>Capability class</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site drainage (i)</td>
<td>Rapidly drained (1) Well drained (2)</td>
<td>Moderately well drained (3)</td>
<td>Imperfectly drained (4)</td>
<td>—</td>
<td>Poorly drained (5) Very poorly drained (6)</td>
<td></td>
</tr>
<tr>
<td>Moisture holding capacity (m)</td>
<td>High (1) Moderately high (2) Moderate (3)</td>
<td>Moderately low (4)</td>
<td>Low (5)</td>
<td>—</td>
<td>Very low (6)</td>
<td></td>
</tr>
<tr>
<td>Nutrient availability (n)</td>
<td>High (1), Moderate (2), Low (3)</td>
<td>Very low (4)</td>
<td>Extremely low (5)</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Rooting conditions (r)</td>
<td>Excellent (1) Very good (2) Good (3) Fair (4)</td>
<td>Low (2)</td>
<td>Moderate (3), High (4)</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Salinity hazard (y)</td>
<td>Nil-low (1), Moderate (2)</td>
<td>—</td>
<td>—</td>
<td>Highly saline (5) Saline (4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flood hazard (f)</td>
<td>Very low-nil (1) Low (2)</td>
<td>Moderate (3), High (4)</td>
<td>Low (4)</td>
<td>Nil (5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential for mechanization (q)</td>
<td>Very high (1), High (2)</td>
<td>Moderate (3)</td>
<td>—</td>
<td>Low (4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil workability (k)</td>
<td>High (1) Moderate (2) Low (3)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind erosion hazard (w)</td>
<td>Low (1), Moderately low (2), Moderate (3)</td>
<td>High (4)</td>
<td>Very high (5)</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Water erosion hazard (e)</td>
<td>Very low (1), Low (2)</td>
<td>Moderate (3)</td>
<td>High (4)</td>
<td>—</td>
<td>Very high (5)</td>
<td></td>
</tr>
<tr>
<td>Soil structural decline hazard (s)</td>
<td>Low (1) Moderate (2) High (3)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* See descriptive tables for land qualities in Appendix 3.

Note: The numerals in parentheses correspond to the numerical ratings as given for each land quality in the corresponding tables in Appendix 3.
Table A4.2. Land capability rating for wine grapes

<table>
<thead>
<tr>
<th>Land quality*</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site drainage (i)</td>
<td>Rapidly drained (1) Well drained (2) Moderately well drained (3)</td>
<td>Imperfectly drained (4)</td>
<td>—</td>
<td>—</td>
<td>Poorly drained (5) Very poorly drained (6)</td>
</tr>
<tr>
<td>Moisture holding capacity (m)</td>
<td>High (1), Moderately high (2), Moderate (3)</td>
<td>—</td>
<td>Moderately low (4)</td>
<td>Low (5)</td>
<td>Very low (6)</td>
</tr>
<tr>
<td>Nutrient availability (n)</td>
<td>Low (3)</td>
<td>Moderate (2), Very low (4)</td>
<td>High (1), Extremely low (5)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Rooting conditions (r)</td>
<td>Excellent (1), Very good (2)</td>
<td>Good (3)</td>
<td>—</td>
<td>Fair (4)</td>
<td>Poor (5)</td>
</tr>
<tr>
<td>Salinity hazard (y)</td>
<td>Nil-low (1), Moderate (2)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Highly saline (5) Saline (4)</td>
</tr>
<tr>
<td>Flood hazard (f)</td>
<td>Nil-very low (1)</td>
<td>Low (2)</td>
<td>Moderate (3)</td>
<td>High (4)</td>
<td>—</td>
</tr>
<tr>
<td>Potential for mechanization (q)</td>
<td>Very high (1), High (2)</td>
<td>Moderate (3)</td>
<td>—</td>
<td>Low (4)</td>
<td>Nil (5)</td>
</tr>
<tr>
<td>Soil workability (k)</td>
<td>High (1)</td>
<td>Moderate (2)</td>
<td>Low (3)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Wind erosion hazard (w)</td>
<td>Low (1), Moderately low (2), Moderate (3)</td>
<td>High (4)</td>
<td>Very high (5)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Water erosion hazard (e)</td>
<td>Very low (1), Low (2)</td>
<td>Moderate (3)</td>
<td>High (4)</td>
<td>—</td>
<td>Very high (5)</td>
</tr>
<tr>
<td>Soil structural decline hazard (s)</td>
<td>Low (1)</td>
<td>Moderate (2)</td>
<td>High (3)</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

* See descriptive tables for land qualities in Appendix 3.

Note: The numerals in parentheses correspond to the numerical ratings as given for each land quality in the corresponding tables in Appendix 3.
Table A4.3. Land capability rating table for dried vine fruit

<table>
<thead>
<tr>
<th>Land quality*</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site drainage (i)</td>
<td>Rapidly drained (1)</td>
<td>—</td>
<td>Imperfectly drained (4)</td>
<td>—</td>
<td>Poorly drained (5)</td>
</tr>
<tr>
<td></td>
<td>Well drained (2)</td>
<td>—</td>
<td>—</td>
<td></td>
<td>Very poorly drained (6)</td>
</tr>
<tr>
<td></td>
<td>Moderately well drained (3)</td>
<td>—</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture holding capacity (m)</td>
<td>High (1), Moderately high (2)</td>
<td>Moderate (3)</td>
<td>Moderately low (4)</td>
<td>Low (5)</td>
<td>Very low (6)</td>
</tr>
<tr>
<td>Nutrient availability (n)</td>
<td>Low (3)</td>
<td>Moderate (2)</td>
<td>High (1), Very low (4)</td>
<td>Extremely low (5)</td>
<td>—</td>
</tr>
<tr>
<td>Rooting conditions (r)</td>
<td>Excellent (1)</td>
<td>Good (3)</td>
<td>—</td>
<td>Fair (4)</td>
<td>Poor (5)</td>
</tr>
<tr>
<td>Salinity hazard (y)</td>
<td>Nil-low (1), Moderate (2)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Highly saline (5)</td>
</tr>
<tr>
<td>Flood hazard (f)</td>
<td>Nil-very low (1), Low (2)</td>
<td>Moderate (3)</td>
<td>High (4)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Potential for mechanization (q)</td>
<td>Very high (1), High (2)</td>
<td>Moderate (3)</td>
<td>—</td>
<td>Low (4)</td>
<td>Nil (5)</td>
</tr>
<tr>
<td>Soil workability (k)</td>
<td>High (1)</td>
<td>Moderate (2)</td>
<td>Low (3)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Wind erosion hazard (w)</td>
<td>Low (1), Moderately low (2), Moderate (3)</td>
<td>High (4)</td>
<td>Very high (5)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Water erosion hazard (e)</td>
<td>Very low (1), Low (2)</td>
<td>Moderate (3)</td>
<td>High (4)</td>
<td>—</td>
<td>Very high (5)</td>
</tr>
<tr>
<td>Soil structural decline hazard (s)</td>
<td>Low (1)</td>
<td>Moderate (2)</td>
<td>High (3)</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

* See descriptive tables for land qualities in Appendix 3.

Note: The numerals in parentheses correspond to the numerical ratings as given for each land quality in the corresponding tables in Appendix 3.
<table>
<thead>
<tr>
<th>Land quality*</th>
<th>I</th>
<th>II</th>
<th>Capability class  III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site drainage (i)</td>
<td>Rapidly drained (1)</td>
<td>Well drained (2)</td>
<td></td>
<td>Moderately well drained (3)</td>
<td></td>
</tr>
<tr>
<td>Moisture holding capacity (m)</td>
<td>High (1), Moderately high (2), Moderate (3)</td>
<td>Moderately low (4), Low (5)</td>
<td></td>
<td>Very low (6)</td>
<td></td>
</tr>
<tr>
<td>Nutrient availability (n)</td>
<td>High (1), Moderate (2)</td>
<td>Low (3), Very low (4)</td>
<td></td>
<td>Extremely low (5)</td>
<td></td>
</tr>
<tr>
<td>Rooting conditions (r)</td>
<td>Excellent (1), Very good (2)</td>
<td>Good (3)</td>
<td></td>
<td></td>
<td>Fair (4), Poor (5)</td>
</tr>
<tr>
<td>Salinity hazard (g)</td>
<td>Nil-low (1)</td>
<td></td>
<td>Moderate (2)</td>
<td></td>
<td>Highly saline (5) Saline (4)</td>
</tr>
<tr>
<td>Flood hazard (f)</td>
<td>Nil-very low (1), Low (2)</td>
<td></td>
<td></td>
<td></td>
<td>Moderate (3), High (4)</td>
</tr>
<tr>
<td>Potential for mechanization (q)</td>
<td>Very high (1), High (2)</td>
<td>Moderate (3)</td>
<td></td>
<td>Low (4)</td>
<td>Nil (5)</td>
</tr>
<tr>
<td>Soil workability (k)</td>
<td>High (1)</td>
<td>Moderate (2)</td>
<td>Low (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind erosion hazard (w)</td>
<td>Low (1), Moderately low (2), Moderate (3), High (4)</td>
<td>Very high (5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water erosion hazard (e)</td>
<td>Very low (1), Low (2)</td>
<td>Moderate (3)</td>
<td>High (4)</td>
<td></td>
<td>Very high (5)</td>
</tr>
<tr>
<td>Soil structural decline hazard (s)</td>
<td>Low (1), Moderate (2)</td>
<td>High (3)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* See descriptive tables for land qualities in Appendix 3.

Note: The numerals in parentheses correspond to the numerical ratings as given for each land quality in the corresponding tables in Appendix 3.
Table A4.5. Land capability rating table for stone fruit

<table>
<thead>
<tr>
<th>Land quality*</th>
<th>I</th>
<th>II</th>
<th>Capability class</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site drainage (i)</td>
<td>Rapidly drained (1) Well drained (2)</td>
<td>—</td>
<td>Moderately well drained (3)</td>
<td>Imperfectly drained (4)</td>
<td>Poorly drained (5) Very poorly drained (6)</td>
</tr>
<tr>
<td>Moisture holding capacity (m)</td>
<td>High (1), Moderately high (2), Moderate (3)</td>
<td>Moderately low (4), Low (5)</td>
<td>Very low (6)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Nutrient availability (n)</td>
<td>High (1), Moderate (2), Low (3)</td>
<td>Very low (4)</td>
<td>Extremely low (5)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Rooting conditions (r)</td>
<td>Excellent (1), Very good (2)</td>
<td>Good (3)</td>
<td>Fair (4)</td>
<td>—</td>
<td>Poor (5)</td>
</tr>
<tr>
<td>Salinity hazard (y)</td>
<td>Nil-low (1)</td>
<td>—</td>
<td>Moderate (2)</td>
<td>—</td>
<td>Highly saline (5) Saline (4)</td>
</tr>
<tr>
<td>Flood hazard (f)</td>
<td>Nil-very low (1)</td>
<td>Low (2)</td>
<td>Moderate (3)</td>
<td>High (4)</td>
<td>—</td>
</tr>
<tr>
<td>Potential for mechanization (q)</td>
<td>Very high (1), High (2)</td>
<td>Moderate (3)</td>
<td>—</td>
<td>Low (4)</td>
<td>Nil (5)</td>
</tr>
<tr>
<td>Soil workability (k)</td>
<td>High (1)</td>
<td>Moderate (2)</td>
<td>Low (3)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Wind erosion hazard (w)</td>
<td>Low (1), Moderately low (2), Moderate (3), High (4)</td>
<td>Very high (5)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Water erosion hazard (e)</td>
<td>Very low (1), Low (2)</td>
<td>Moderate (3)</td>
<td>High (4)</td>
<td>—</td>
<td>Very high (5)</td>
</tr>
<tr>
<td>Soil structural decline hazard (s)</td>
<td>Low (1), Moderate (2)</td>
<td>High (3)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

* See descriptive tables for land qualities in Appendix 3.

Note: The numerals in parentheses correspond to the numerical ratings as given for each land quality in the corresponding tables in Appendix 3.
Table A4.6. Land capability rating table for market gardening

<table>
<thead>
<tr>
<th>Land quality*</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site drainage (I)</td>
<td>Rapidly drained (1)</td>
<td>Well drained (2)</td>
<td>Moderately well drained (3)</td>
<td>—</td>
<td>Imperfectly drained (4)</td>
</tr>
<tr>
<td>Moisture holding capacity (m)</td>
<td>High (1), Moderately high (2), Moderate (3), Moderately low (4), Low (5)</td>
<td>—</td>
<td>Very low (6)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Nutrient availability (n)</td>
<td>High (1), Moderate (2), Low (3), Very low (4)</td>
<td>Extremely low (5)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Rooting conditions (r)</td>
<td>Excellent (1), Very good (2)</td>
<td>Good (3)</td>
<td>Fair (4)</td>
<td>—</td>
<td>Poor (5)</td>
</tr>
<tr>
<td>Salinity hazard (y)</td>
<td>Nil-low (1)</td>
<td>—</td>
<td>Moderate (2)</td>
<td>—</td>
<td>Highly saline (5)</td>
</tr>
<tr>
<td>Flood hazard (f)</td>
<td>Nil-very low (1)</td>
<td>Low (2)</td>
<td>—</td>
<td>—</td>
<td>Moderate (3), Saline (4)</td>
</tr>
<tr>
<td>Potential for mechanization (q)</td>
<td>Very high (1)</td>
<td>High (2)</td>
<td>Moderate (3)</td>
<td>Low (4)</td>
<td>Nil (5)</td>
</tr>
<tr>
<td>Soil workability (k)</td>
<td>High (1)</td>
<td>Moderate (2)</td>
<td>—</td>
<td>Low (3)</td>
<td>—</td>
</tr>
<tr>
<td>Wind erosion hazard (w)</td>
<td>Low (1), Moderately low (2), Moderate (3), High (4), Very high (5)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Water erosion hazard (e)</td>
<td>Very low (1)</td>
<td>Low (2)</td>
<td>Moderate (3)</td>
<td>High (4)</td>
<td>Very high (5)</td>
</tr>
<tr>
<td>Soil structural decline hazard (s)</td>
<td>Low (1)</td>
<td>Moderate (2)</td>
<td>—</td>
<td>High (3)</td>
<td>—</td>
</tr>
</tbody>
</table>

*See descriptive tables for land qualities in Appendix 3.

Note: The numerals in parentheses correspond to the numerical ratings as given for each land quality in the corresponding tables in Appendix 3.
Maps available on the GIS

The maps for this project were produced on a computer graphics system by the Geographic Information Systems (GIS) group of the Department of Agriculture. The information available on the system is outlined below. Different sets of information can be overlaid or viewed separately on either a graphics terminal or on a hard copy plot (colour or black/white).

- Locality names, roads, road names, rivers and tributaries, cadastre
- Soil map (from Pym 1955)
- Land capability interpretive maps for:
  - Table grapes
  - Wine grapes
  - Dried vine fruit
  - Stone fruit
  - Citrus
  - Market gardening
- Phosphate retention ability^(1)^
- Nitrate retention ability^(1)^

^(1)^ from Moore (1990).

Note: These maps can be obtained through

The Commercial Land Resource Information Group
Department of Agriculture,
Western Australia
Baron-Hay Court
South Perth, W.A., 6151
Tel: (09) 368 3333
Fax: (09) 368 3355
Groundwater resources of the Swan Valley

The fresh groundwater resources of the Swan Valley are in three main aquifer systems; the unconfined superficial formation and the confined Osborne and Leederville formations. The three formations are multi-layered aquifers containing strata controlled flow systems which may be discrete or in lateral or vertical hydraulic connection with adjacent aquifers. The following descriptions of each aquifer have been taken from Steen (1984) and Allen (1980).

Superficial formations

The shallow, unconfined superficial formations overlie both the Osborne and Leederville formations. They are of variable thickness and consist largely of sand and clay. The clay content increases in an easterly direction with a corresponding decrease in groundwater storage.

Water from the Gnangara Mound is discharged, horizontally, east through the formation to the Swan River and into tributaries and also downwards through the Osborne formation to the Leederville formation. Along the base of the valley the Osborne and Leederville formations discharge vertically upwards into the superficial formations. This groundwater is removed by either evapotranspiration or drainage into the Swan River. In the eastern part of the Swan Valley, groundwater in the superficial formation flows westward towards the Swan River.

Water quality in the superficial formations deteriorates in areas close to the Swan River, or along the streams that feed into the Swan River from the east, such as Jane and Susannah Brooks.

Osborne formation

The Osborne formation overlies most of the western flow system of the Leederville formation. The formation is about 160 m thick in the western part of the Swan Groundwater Area, gradually thinning to the east until it pinches out east of the Swan River. It consists of variable beds of shale and clayey sands with some sandy facies.

Groundwater in the Osborne formation originates as downward seepage from the superficial formations, principally in the area of the Gnangara mound. From the Gnangara mound water discharges downward to the Leederville formation, while in the vicinity of the Swan River it discharges upwards to the superficial formation.

Leederville formation

The main aquifers of the Swan Valley are in the sandstone beds of the Leederville formation. The formation is about 300 m thick and dips westward from its eastern limit at the Darling Scarp. The formation consists of alternating layers of sandstone and shale and is underlain by the South Perth shale, which effectively stops downward movement.

The major flow system of the area is the western system of the Leederville formation. Recharge occurs to the west of the Swan Valley where there is downward seepage from the Gnangara mound, through sandy facies in the Osborne formation to the Leederville formation. Groundwater flows eastward from this area to discharge into the overlying superficial formations.

Water quality within the Leederville formation deteriorates with depth. The upper half generally contains potable water, while the lower half contains water with salinities ranging from 1000 mg/L to 4000 mg/L TSS*. However, in the area of discharge the quality of groundwater in the upper Leederville formation deteriorates east of the Swan River.

* TSS = Total soluble solids.
Appendix 7.
Maps
(2 sheets)
Soils (Pym, 1955) plus roads and cadastral information (1:25,000).
Land capability interpretative map for table grape production (1:50,000).